

Testing results for HICUM Level Version 2.31

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1 Introduction

The document shows the testing results for the HICUM Level 2 Version 2.31. Two kind of test were performed.

- Standard characteristics with model cards for different parts of the transistor and
- Special simulations verifying second-order effects.

1.1 Model cards and VA-code

Two comparisons are performed. The first compares **v2.31** to **v2.24** in order to show complete backward compatibility to versions used in production. The second comparison is between **v2.31** to **v2.30** in order show an error free continuation of the HICUM code.

Therefore, two kinds of model cards for each simulation have been used. One using only parameters from **v2.24** and one taking also the parameters from **v2.30** into account. Effects that are new in **v2.31** are shown separately.

The different model cards used contain parameters corresponding to

- Only the 1D transistor,
- Internal transistor, i.e. 1D and internal base resistance,
- Complete transistor,
- Complete transistor with self-heating effects,
- Complete transistor including substrate transistor,
- Complete transistor including substrate transistor and substrate network,
- 1D transistor including vertical NQS effects,
- Internal transistor including lateral NQS effects and
- 1D transistor using the non-ideality factor m_{ef} .

1.2 Special characteristics

A final chapter describes some high order effects of HICUM Level 2. These include

- Vertical NQS effect,

1 Introduction

- Lateral NQS effect,
- Temperature dependent thermal resistance and
- Correlated noise modeling.

2 1D Transistor

2.1 Model cards

2.1.1 Version 2.31, compatible to 2.24

```
c10=2.0175e-032 qp0=2.155e-016 ich=0 hfe=1.8331
hfc=0.05 hjei=0.034883 hjci=0.0026778 ibeis=2.82e-020
mbei=1.012 ireis=2.7167e-015 mrei=2.263 ibeps=0 mbep=1
ireps=0 mrep=2 mcf=1 tbhrec=1e-012 ibcis=1.165e-019
mbci=1.066 ibcx=0 mbcx=1 ibets=0 abet=40 tunode=1
favl=240.3 qavl=1.1756e-013 alfav=-0.009966 alqav=-0.0009569
rbi0=0 rbx=0 fgeo=0.6557 fdqr0=0 fcrbi=0 fqi=1 re=0
rcx=0 itss=0 msf=1 iscs=0 msc=1 tsf=0 rsu=0 csu=0
cjei0=9.3264e-015 vdei=0.87043 zei=0.20065 ajei=2.1953 cjep0=1e-020
vdep=0.9 zep=0.5 ajep=2.5 cjc0=7.4192e-015 vdc0=0.73351
zci=0.36198 vptci=3.2461 cjc0=1e-020 vdc0=0.7 zcx=0.4
vptcx=100 fbcpar=0 fbepar=1 cjs0=0 vds=0.6 zs=0.5 vpts=100
t0=2.2784e-013 dt0h=1.0591e-013 tbvl=1.5456e-014
tef0=4.4727e-013 gtfe=1.4744 thcs=1e-011 ahc=0.06 fthc=0.5
rci0=19.44 vlim=1.429 vces=0.001 vpt=18 tr=0 cbepar=0
cbcp=0 alqf=0.16667 alit=0.33333 flnqs=0 kf=0 af=2
cfbe=-1 latb=0 latl=0 vgb=0.9 alt0=0.0025354 kt0=1e-005
zetaci=0.5621 alvs=0.00217 alces=-0.00584 zetarbi=0 zetarbx=0
zetarcx=0 zetare=0 zetacx=1 vge=1.17 vgc=1.17 vgs=1.17
f1vg=-0.00010238 f2vg=0.00043215 zetact=5.3125 zetabet=1.3855
alb=0 flsh=0 rth=0 cth=0 flcomp=2.2 tnom=27 dt=0
zetarth=0 type=1 flcono=0
```

2.1.2 Version 2.31, compatible to 2.30

```
c10=2.0175e-032 qp0=2.155e-016 ich=0 hfe=1.8331
hfc=0.05 hjei=0.034883 hjci=0.0026778 ibeis=2.82e-020
mbei=1.012 ireis=2.7167e-015 mrei=2.263 ibeps=0 mbep=1
ireps=0 mrep=2 mcf=1 tbhrec=1e-012 ibcis=1.165e-019
mbci=1.066 ibcx=0 mbcx=1 ibets=0 abet=40 tunode=1
favl=240.3 qavl=1.1756e-013 alfav=-0.009966 alqav=-0.0009569
rbi0=0 rbx=0 fgeo=0.6557 fdqr0=0 fcrbi=0 fqi=1 re=0
rcx=0 itss=0 msf=1 iscs=0 msc=1 tsf=0 rsu=0 csu=0
```

```

cjei0=9.3264e-015 vdei=0.87043 zei=0.20065 ajei=2.1953 cjep0=1e-020
vdep=0.9 zep=0.5 ajep=2.5 cjci0=7.4192e-015 vdc1=0.73351
zci=0.36198 vptci=3.2461 cjc0=1e-020 vdcx=0.7 zcx=0.4
vptcx=100 fbcpar=0 fbepar=1 cjs0=0 vds=0.6 zs=0.5 vpts=100
t0=2.2784e-013 dt0h=1.0591e-013 tbvl=1.5456e-014
tef0=4.4727e-013 gtfe=1.4744 thcs=1e-011 ahc=0.06 fthc=0.5
rci0=19.44 vlim=1.429 vces=0.001 vpt=18 tr=0 cbepar=0
cbcpar=0 alqf=0.16667 alit=0.33333 flnqs=0 kf=0 af=2
cfbe=-1 latb=0 latl=0 vgb=0.9 alt0=0.0025354 kt0=1e-005
zetaci=0.5621 alvs=0.00217 alces=-0.00584 zetarbi=0 zetarbx=0
zetarcx=0 zetare=0 zetacx=1 vge=1.17 vgc=1.17 vgs=1.17
flvg=-0.00010238 f2vg=0.00043215 zetact=5.3125 zetabet=1.3855
alb=0 flsh=0 rth=0 cth=0 flcomp=2.3 tnom=27 dt=0
zetarth=0 type=1 flcono=0 hf0=0.24679 ahjei=5.912 rhjei=2
vcbar=0.04 icbar=0.003 acbar=1.5 delck=1.8 dvgbe=-0.1103
zetahjei=-0.78133 zetavgbe=0.7 alrth=0

```

2.2 Simulation results

2.2.1 Comparison between version 2.31 and 2.24

Forward gummel

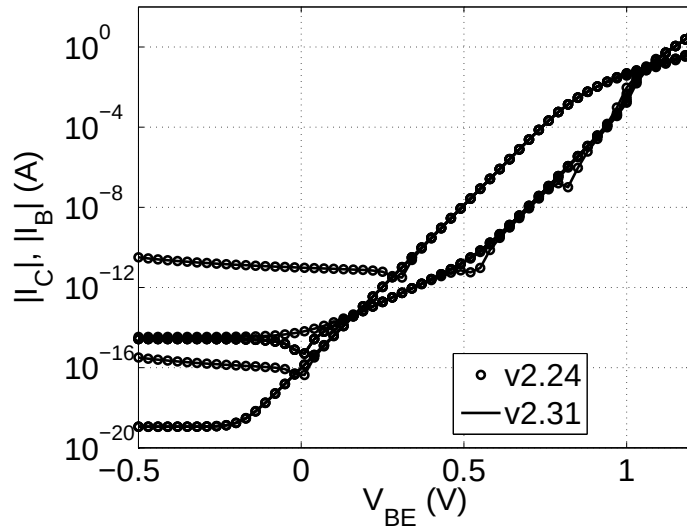


Figure 2.1: Forward gummel at room temperature for $V_{BC} = -0.9...0.3V$

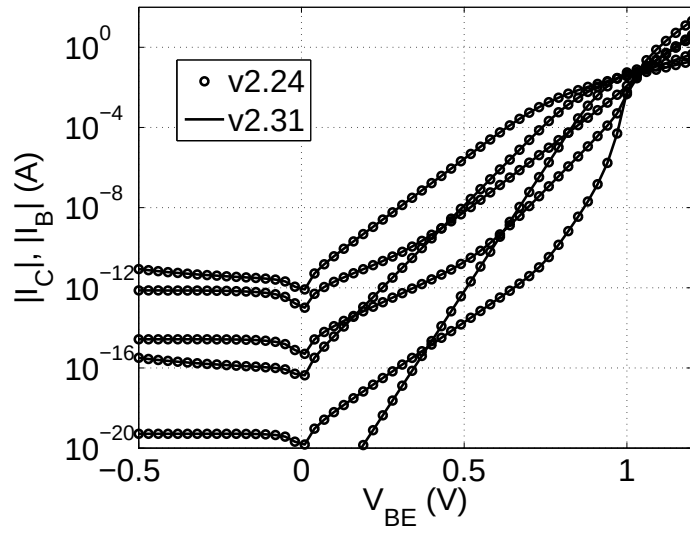


Figure 2.2: Forward gummel at $V_{BC} = 0.0V$ and $T = [200, 300, 400]K$

Reverse gummel

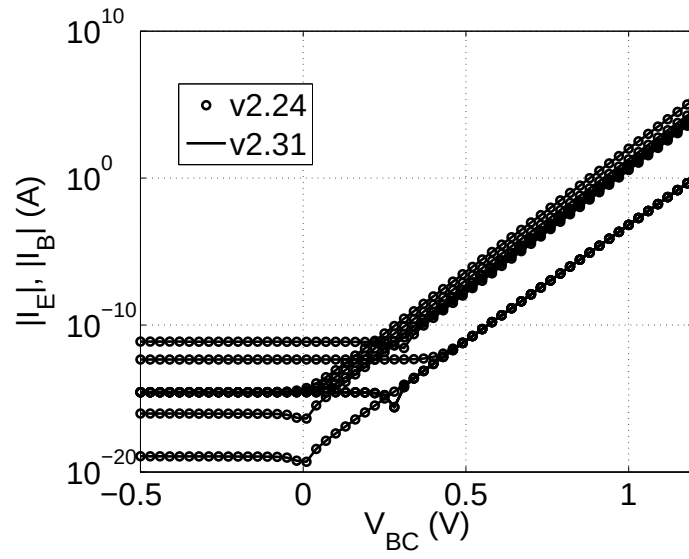


Figure 2.3: Reverse gummel at room temperature for $V_{BE} = -0.9...0.3V$

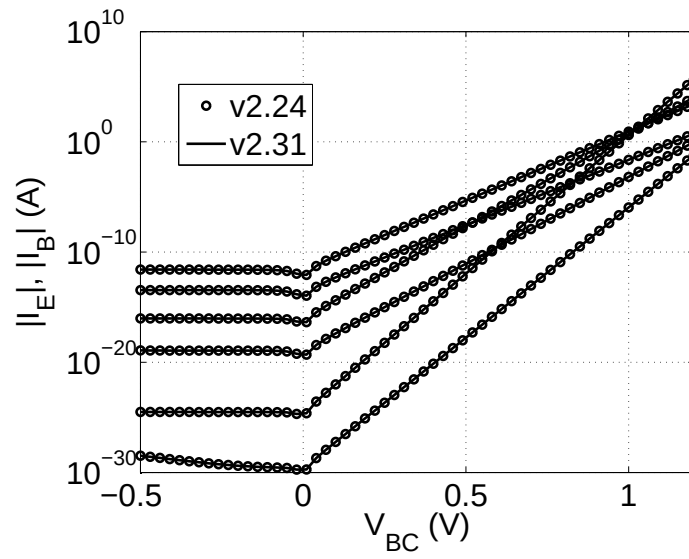
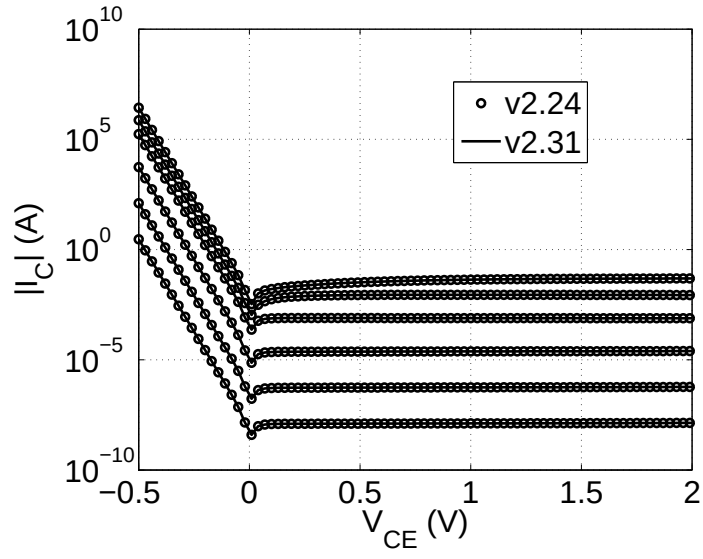
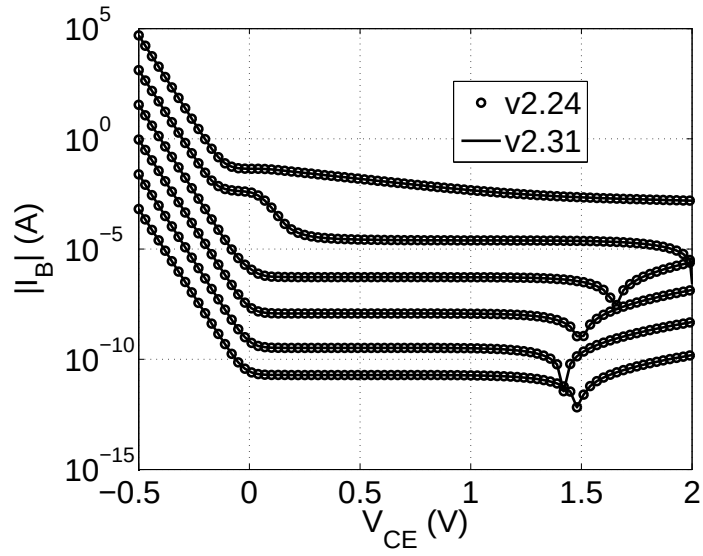


Figure 2.4: Reverse gummel at $V_{BE} = 0.0V$ and $T = [200, 300, 400]K$

Forward output, forced V_{BE} Figure 2.5: Forward output at forced V_{BE} Figure 2.6: Forward output at forced V_{BE}

Forward output, forced I_B

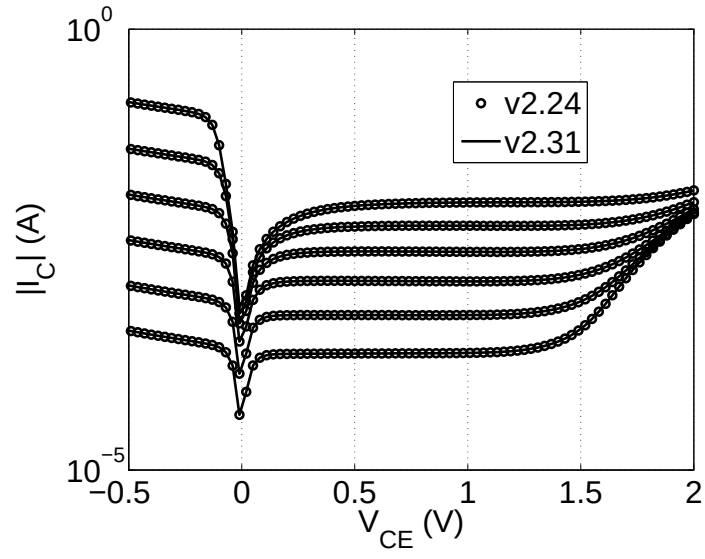


Figure 2.7: Forward output at forced I_B

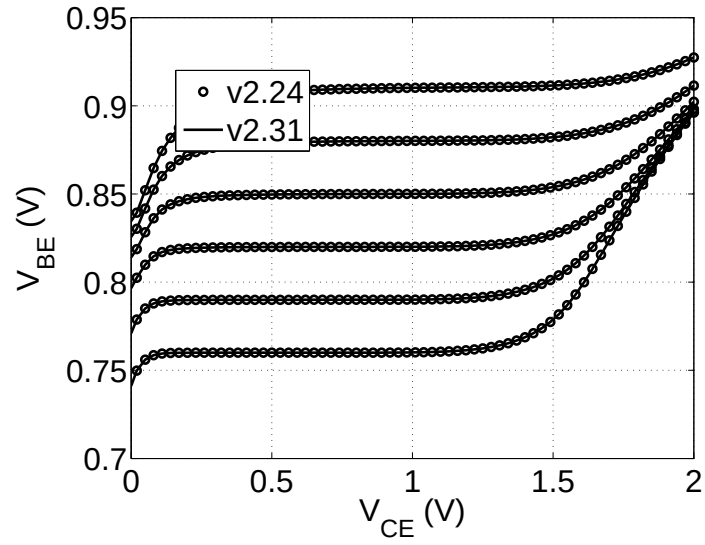


Figure 2.8: Forward output at forced I_B

Small signal results

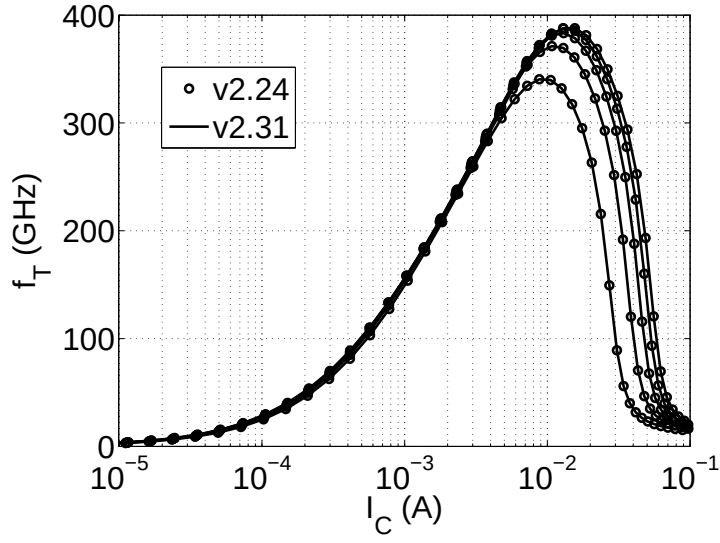


Figure 2.9: Transit frequency versus collector current at room temperature for $V_{BC} = -0.9 \dots 0.3V$

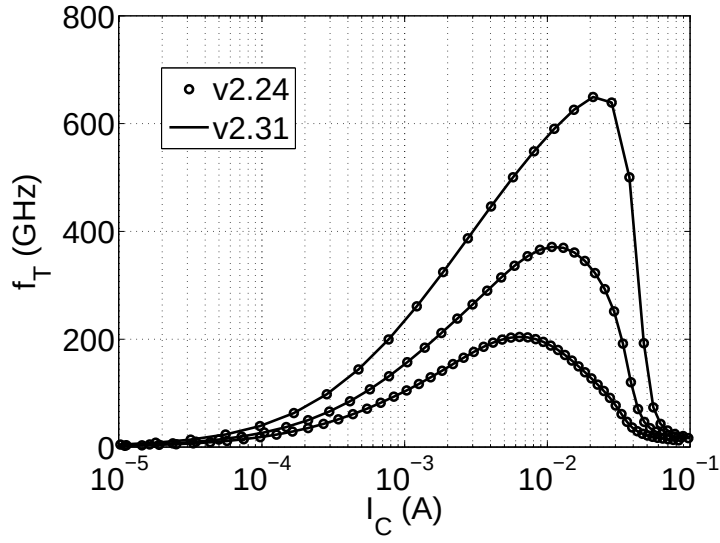


Figure 2.10: Transit frequency versus collector current at $V_{BC} = 0.0V$ and $T = [200, 300, 400] K$

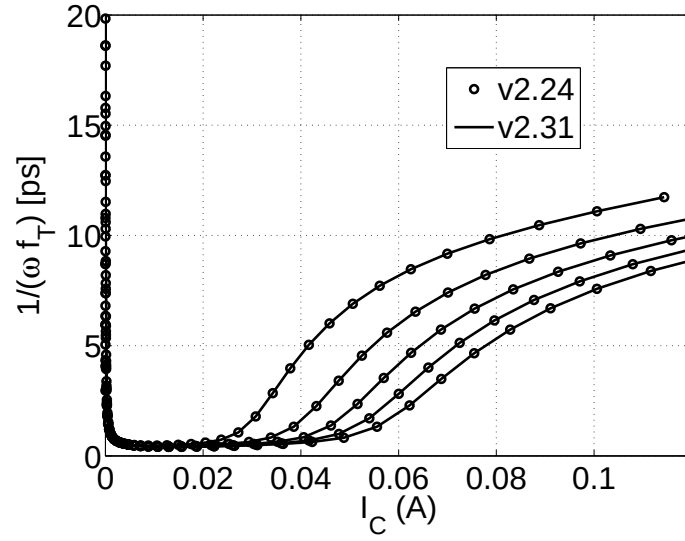


Figure 2.11: Tranist time versus collector current at room temperature for $V_{BC} = -0.9...0.3V$

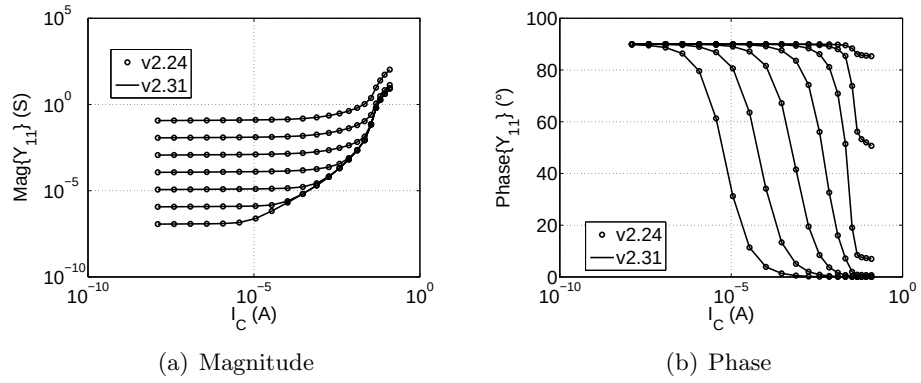


Figure 2.12: Magnitude and phase of Y_{11} versus collector current for $f=1 \text{ MHz}...1 \text{ THz}$ at $V_{BC} = 0.0V$ and room temperature

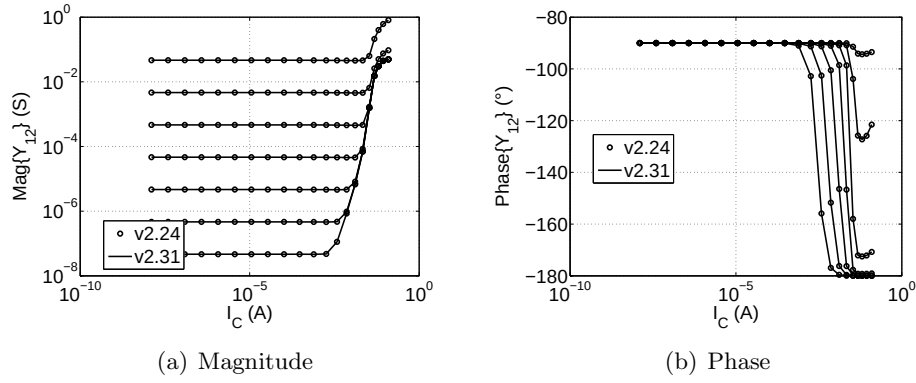


Figure 2.13: Magnitude and phase of Y_{12} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

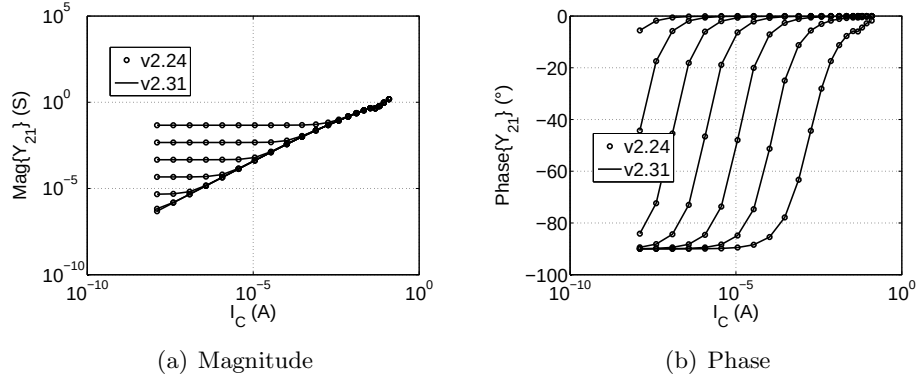


Figure 2.14: Magnitude and phase of Y_{21} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

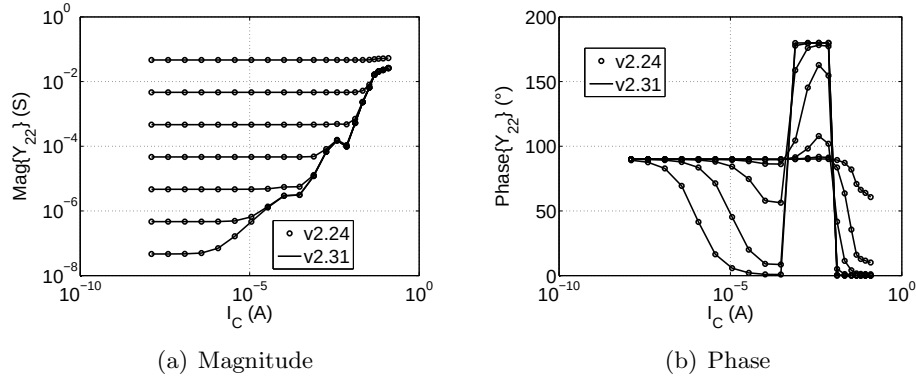


Figure 2.15: Magnitude and phase of Y_{22} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

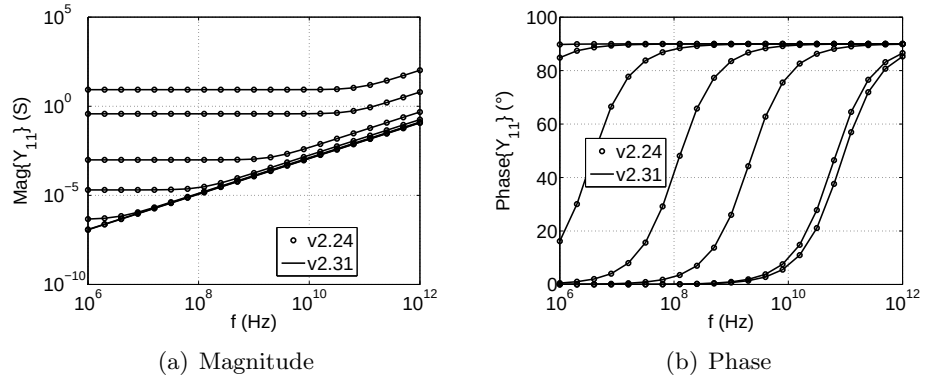


Figure 2.16: Magnitude and phase of Y_{11} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

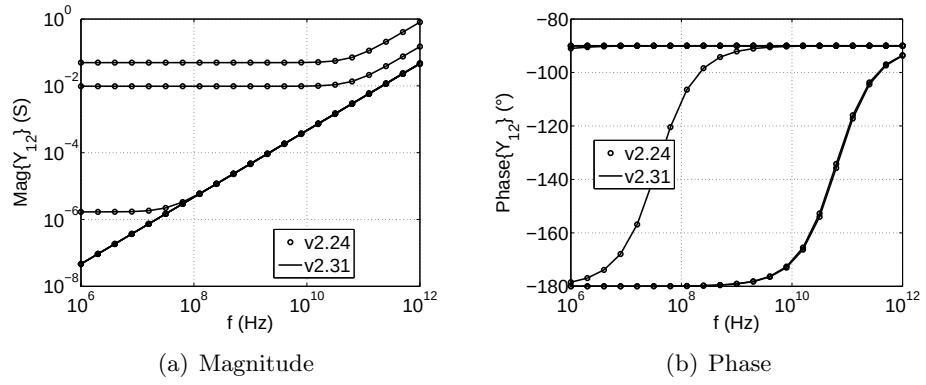


Figure 2.17: Magnitude and phase of Y_{12} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

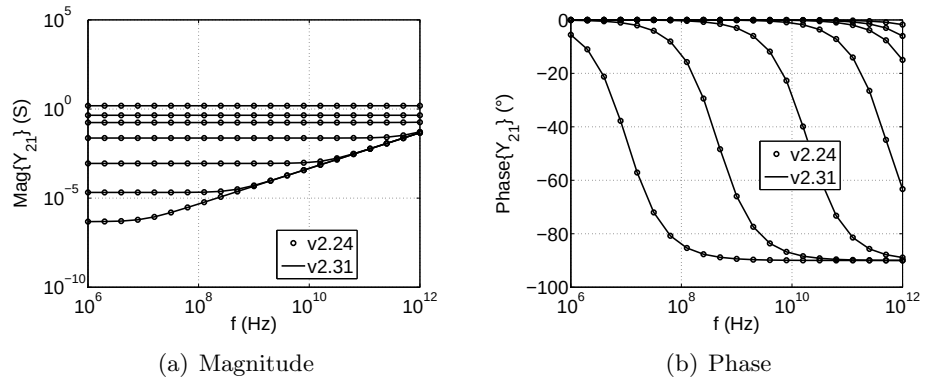


Figure 2.18: Magnitude and phase of Y_{21} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

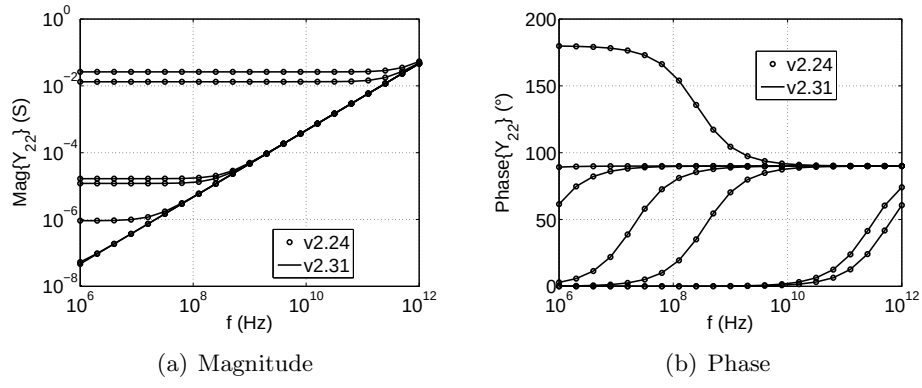


Figure 2.19: Magnitude and phase of Y_{22} versus frequency for $V_{BE} = 0.5 \dots 1.1V$ at $V_{BC} = 0.0V$ and room temperature

Noise modeling

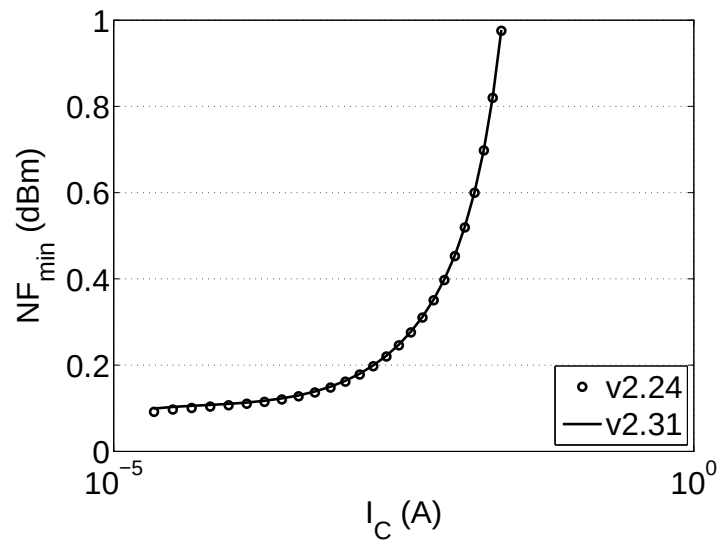


Figure 2.20: Minimum noise figure versus collector current at room temperature

2.2.2 Comparison between version 2.31 and 2.30

Forward gummel

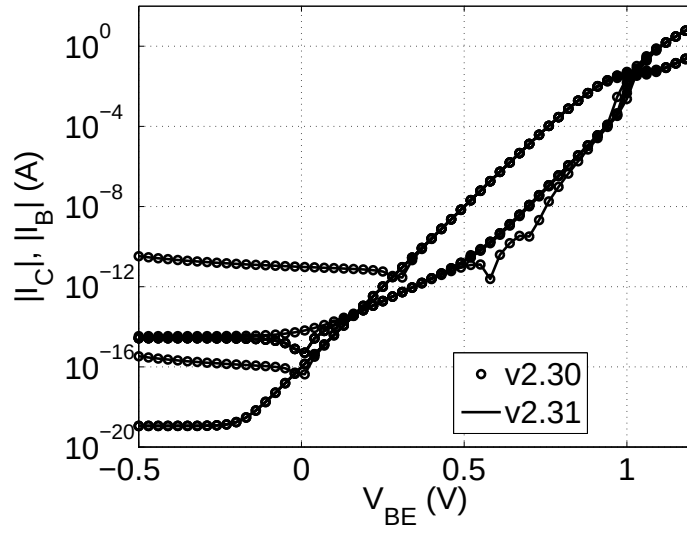


Figure 2.21: Forward gummel at room temperature for $V_{BC} = -0.9...0.3V$

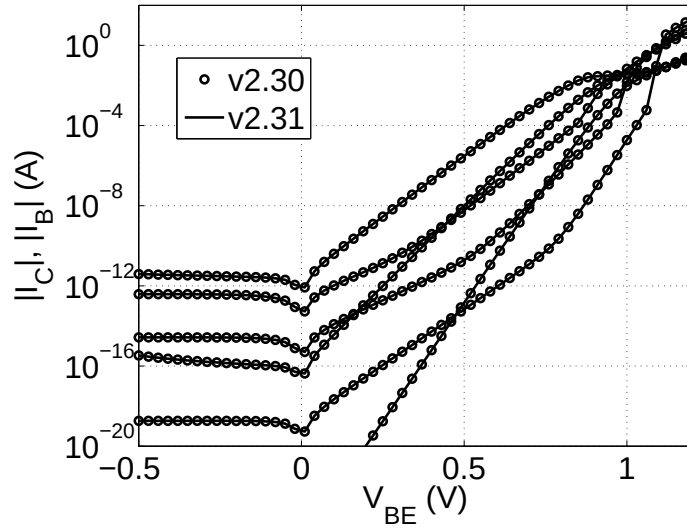


Figure 2.22: Forward gummel at $V_{BC} = 0.0V$ and $T = [200, 300, 400]K$

Reverse gummel

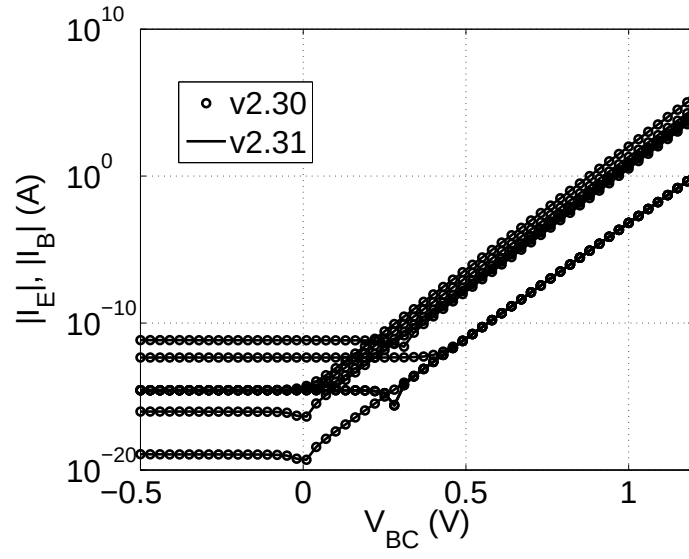


Figure 2.23: Reverse gummel at room temperature for $V_{BE} = -0.9...0.3V$

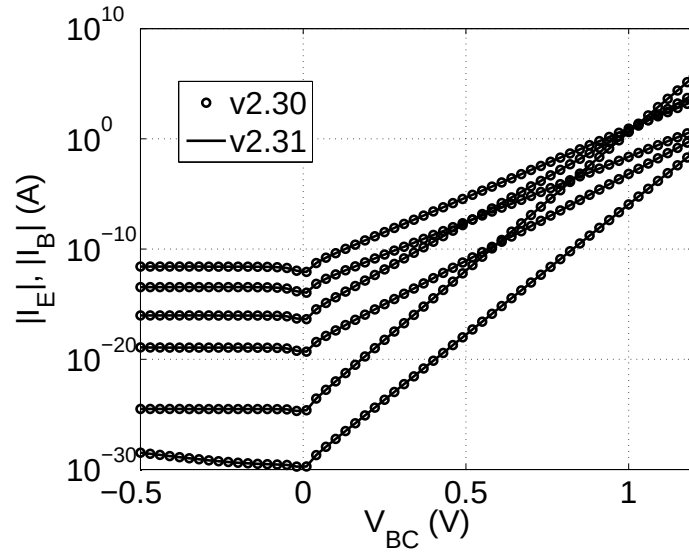
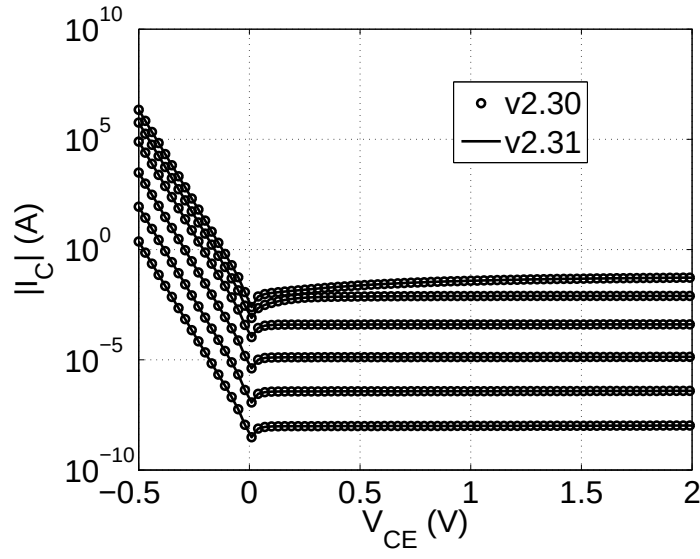
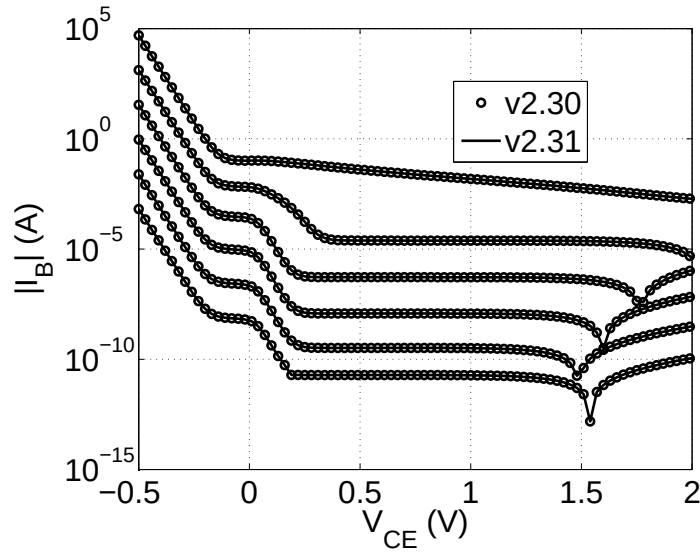


Figure 2.24: Reverse gummel at $V_{BE} = 0.0V$ and $T = [200, 300, 400]K$

Forward output, forced V_{BE} Figure 2.25: Forward output at forced V_{BE} Figure 2.26: Forward output at forced V_{BE}

Forward output, forced I_B

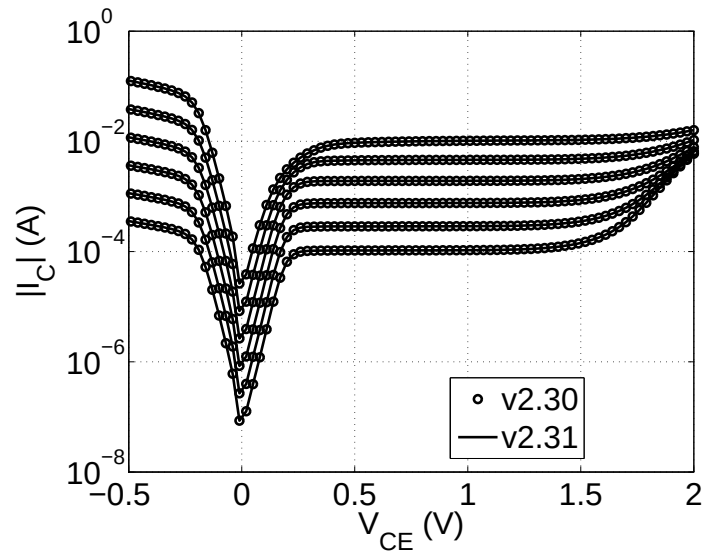


Figure 2.27: Forward output at forced I_B

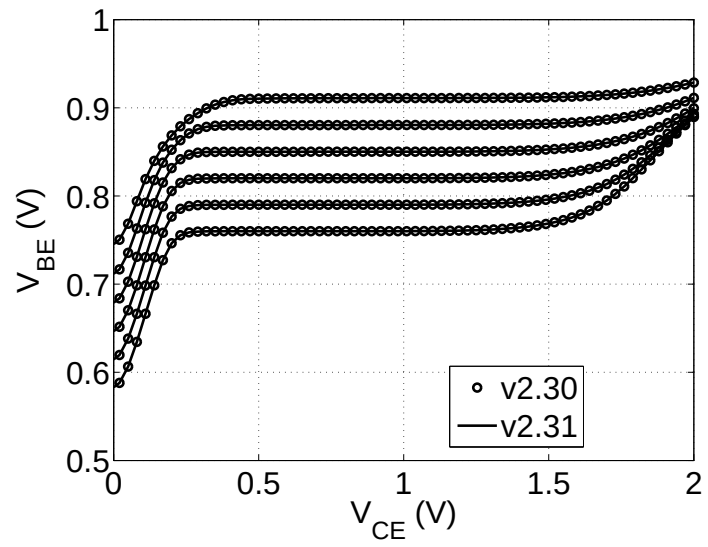


Figure 2.28: Forward output at forced I_B

Small signal results

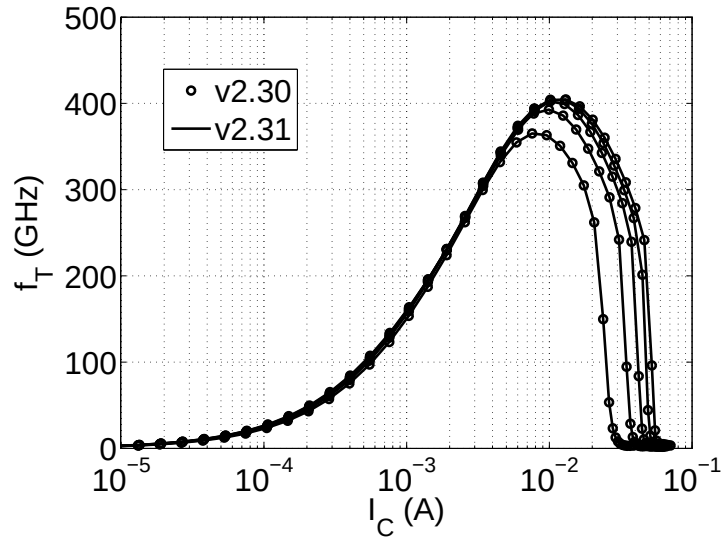


Figure 2.29: Transit frequency versus collector current at room temperature for $V_{BC} = -0.9 \dots 0.3V$

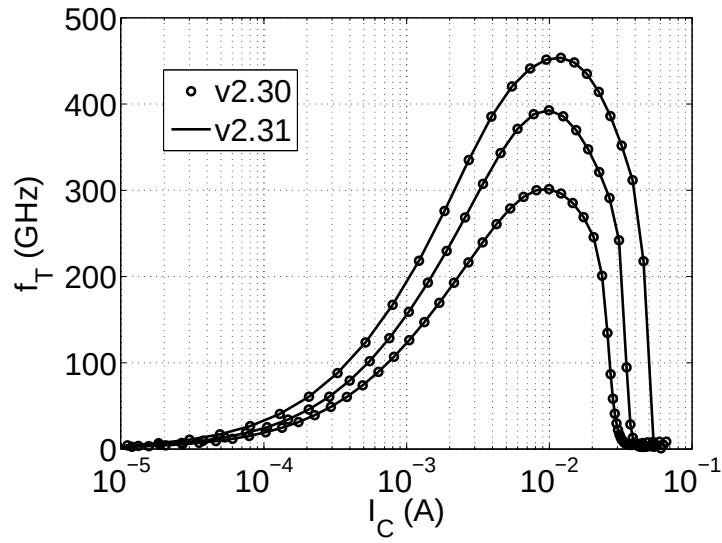


Figure 2.30: Transit frequency versus collector current at $V_{BC} = 0.0V$ and $T = [200, 300, 400]K$

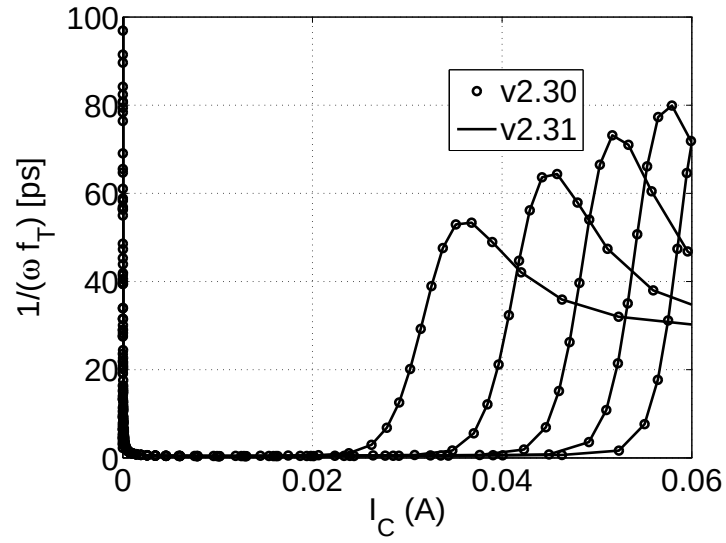


Figure 2.31: Tranist time versus collector current at room temperature for $V_{BC} = -0.9...0.3V$

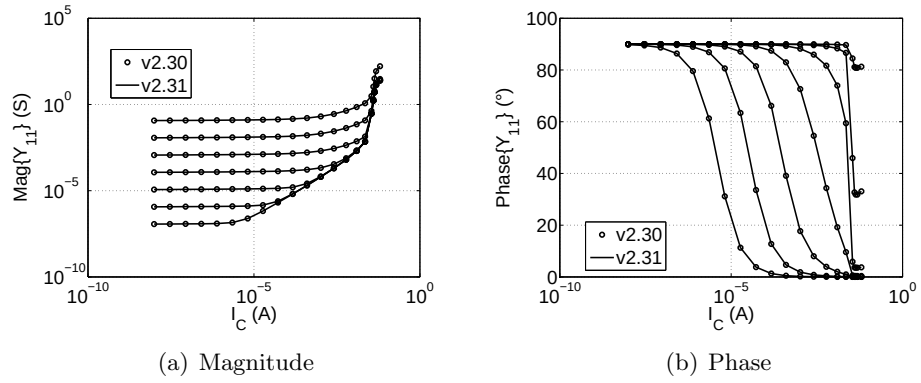


Figure 2.32: Magnitude and phase of Y_{11} versus collector current for $f=1 \text{ MHz}...1 \text{ THz}$ at $V_{BC} = 0.0V$ and room temperature

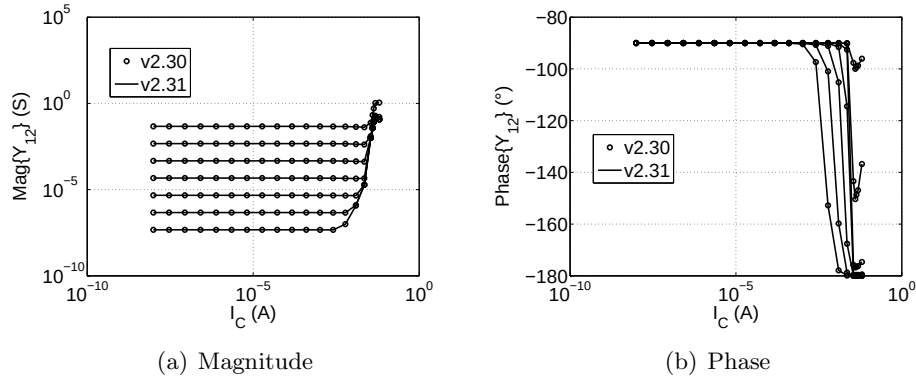


Figure 2.33: Magnitude and phase of Y_{12} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

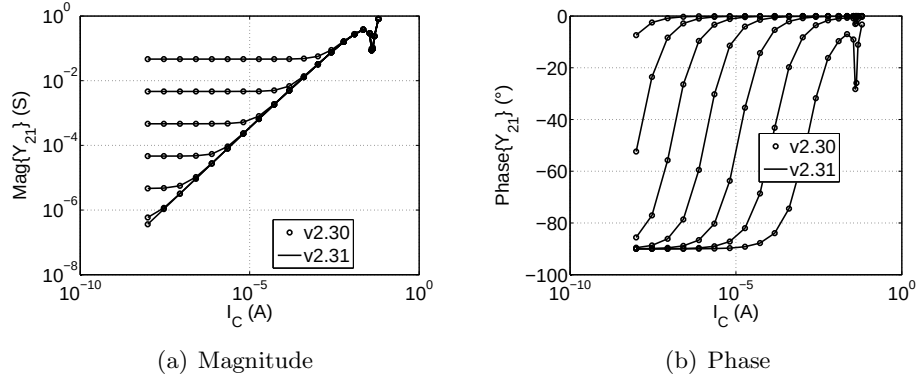


Figure 2.34: Magnitude and phase of Y_{21} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

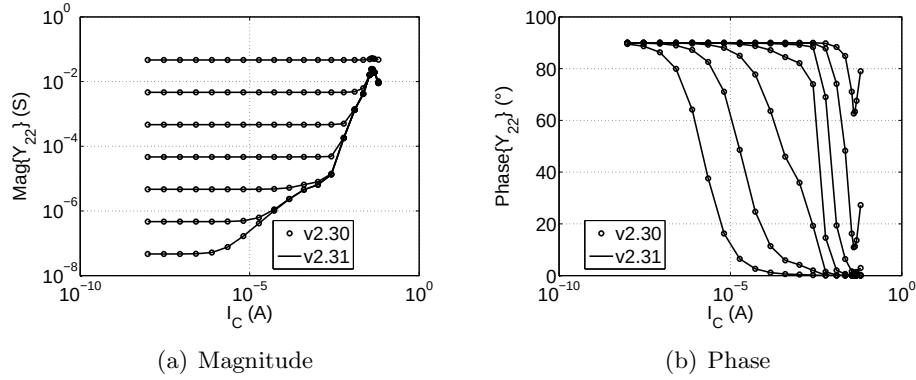


Figure 2.35: Magnitude and phase of Y_{22} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

2 1D Transistor

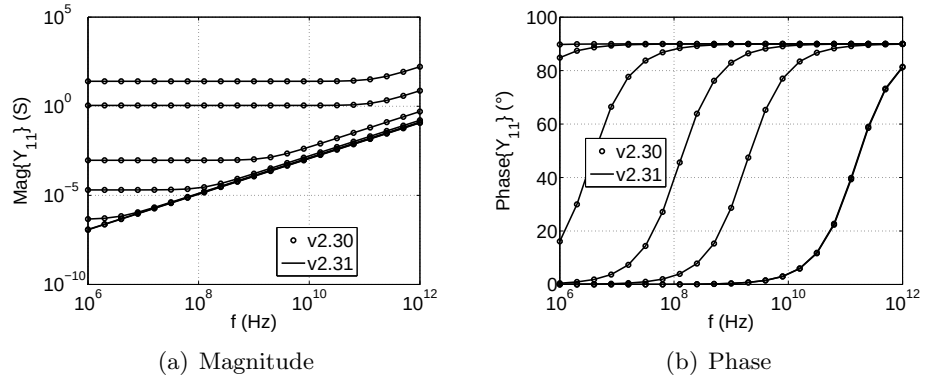


Figure 2.36: Magnitude and phase of Y_{11} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

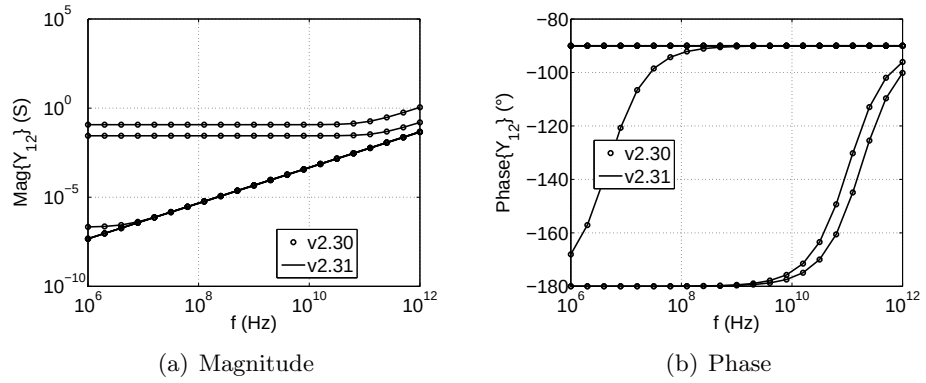


Figure 2.37: Magnitude and phase of Y_{12} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

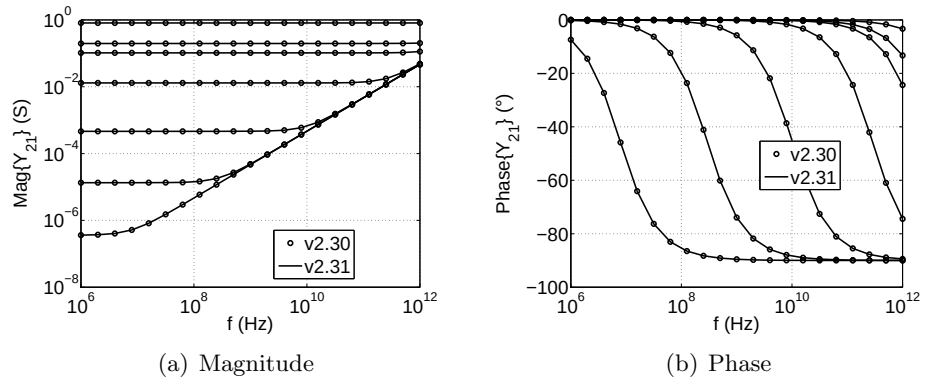


Figure 2.38: Magnitude and phase of Y_{21} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

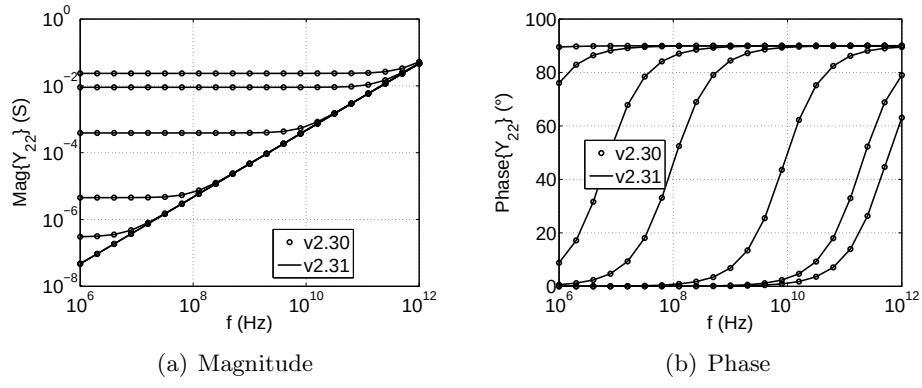


Figure 2.39: Magnitude and phase of Y_{22} versus frequency for $V_{BE} = 0.5 \dots 1.1V$ at $V_{BC} = 0.0V$ and room temperature

Noise modeling

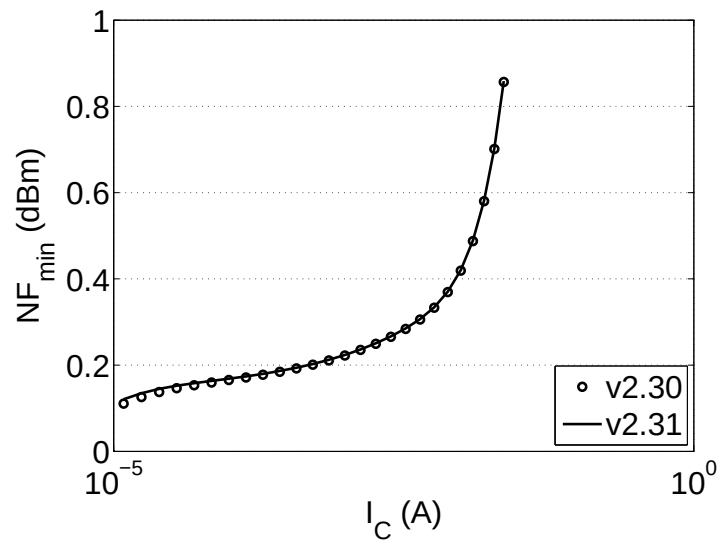


Figure 2.40: Minimum noise figure versus collector current at room temperature

3 Internal transistor, including R_{Bi}

3.1 Model cards

3.1.1 Version 2.31, compatible to 2.24

```
c10=2.0175e-032 qp0=2.155e-016 ich=0 hfe=1.8331
hfc=0.05 hjei=0.034883 hjci=0.0026778 ibeis=2.82e-020
mbei=1.012 ireis=2.7167e-015 mrei=2.263 ibeps=0 mbep=1
ireps=0 mrep=2 mcf=1 tbhrec=1e-012 ibcis=1.165e-019
mbci=1.066 ibcx=0 mbcx=1 ibets=1e-014 abet=40 tunode=1
favl=240.3 qavl=1.1756e-013 alfav=-0.009966 alqav=-0.0009569
rbi0=25 rbx=0 fgeo=0.6557 fdqr0=13 fcrbi=0 fqi=1 re=0
rcx=0 itss=0 msf=1 iscs=0 msc=1 tsf=0 rsu=0 csu=0
cjei0=9.3264e-015 vdei=0.87043 zei=0.20065 ajei=2.1953 cjep0=1e-020
vdep=0.9 zep=0.5 ajep=2.5 cjc0=7.4192e-015 vdc0=0.73351
zci=0.36198 vptci=3.2461 cjc0=1e-020 vdc0=0.7 zcx=0.4
vptcx=100 fbcpar=0 fbepar=1 cjs0=0 vds=0.6 zs=0.5 vpts=100
t0=2.2784e-013 dt0h=1.0591e-013 tbvl=1.5456e-014
tef0=4.4727e-013 gtfe=1.4744 thcs=1e-011 ahc=0.06 fthc=0.5
rci0=19.44 vlim=1.429 vces=0.001 vpt=18 tr=0 cbepar=0
cbcp=0 alqf=0.16667 alit=0.33333 flnqs=0 kf=0 af=2
cfbe=-1 latb=0 latl=0 vgb=0.9 alt0=0.0025354 kt0=1e-005
zetaci=0.5621 alvs=0.00217 alces=-0.00584 zetarbi=0 zetarbx=0
zetarcx=0 zetare=0 zetacx=1 vge=1.17 vgc=1.17 vgs=1.17
f1vg=-0.00010238 f2vg=0.00043215 zetact=5.3125 zetabet=1.3855
alb=0 flsh=0 rth=0 cth=0 flcomp=2.2 tnom=27 dt=0
zetarth=0 type=1 flcono=0
```

3.1.2 Version 2.31, compatible to 2.30

```
c10=2.0175e-032 qp0=2.155e-016 ich=0 hfe=1.8331
hfc=0.05 hjei=0.034883 hjci=0.0026778 ibeis=2.82e-020
mbei=1.012 ireis=2.7167e-015 mrei=2.263 ibeps=0 mbep=1
ireps=0 mrep=2 mcf=1 tbhrec=1e-012 ibcis=1.165e-019
mbci=1.066 ibcx=0 mbcx=1 ibets=1e-014 abet=40 tunode=1
favl=240.3 qavl=1.1756e-013 alfav=-0.009966 alqav=-0.0009569
rbi0=25 rbx=0 fgeo=0.6557 fdqr0=13 fcrbi=0 fqi=1 re=0
rcx=0 itss=0 msf=1 iscs=0 msc=1 tsf=0 rsu=0 csu=0
```

3 Internal transistor, including R_{Bi}

```
cjei0=9.3264e-015 vdei=0.87043 zei=0.20065 ajei=2.1953 cjep0=1e-020
vdep=0.9 zep=0.5 ajep=2.5 cjci0=7.4192e-015 vdc1=0.73351
zci=0.36198 vptci=3.2461 cjc0=1e-020 vdcx=0.7 zcx=0.4
vptcx=100 fbcpar=0 fbepar=1 cjs0=0 vds=0.6 zs=0.5 vpts=100
t0=2.2784e-013 dt0h=1.0591e-013 tbvl=1.5456e-014
tef0=4.4727e-013 gtfe=1.4744 thcs=1e-011 ahc=0.06 fthc=0.5
rci0=19.44 vlim=1.429 vces=0.001 vpt=18 tr=0 cbepar=0
cbcpar=0 alqf=0.16667 alit=0.33333 flnqs=0 kf=0 af=2
cfbe=-1 latb=0 latl=0 vgb=0.9 alt0=0.0025354 kt0=1e-005
zetaci=0.5621 alvs=0.00217 alces=-0.00584 zetarbi=0 zetarbx=0
zetarcx=0 zetare=0 zetacx=1 vge=1.17 vgc=1.17 vgs=1.17
flvg=-0.00010238 f2vg=0.00043215 zetact=5.3125 zetabet=1.3855
alb=0 flsh=0 rth=0 cth=0 flcomp=2.3 tnom=27 dt=0
zetarth=0 type=1 flcono=0 hf0=0.24679 ahjei=5.912 rhjei=2
vcbar=0.04 icbar=0.003 acbar=1.5 delck=1.8 dvgbe=-0.1103
zetahjei=-0.78133 zetavgbe=0.7 alrth=0
```

3.2 Simulation results

3.2.1 Comparison between version 2.31 and 2.24

Forward gummel

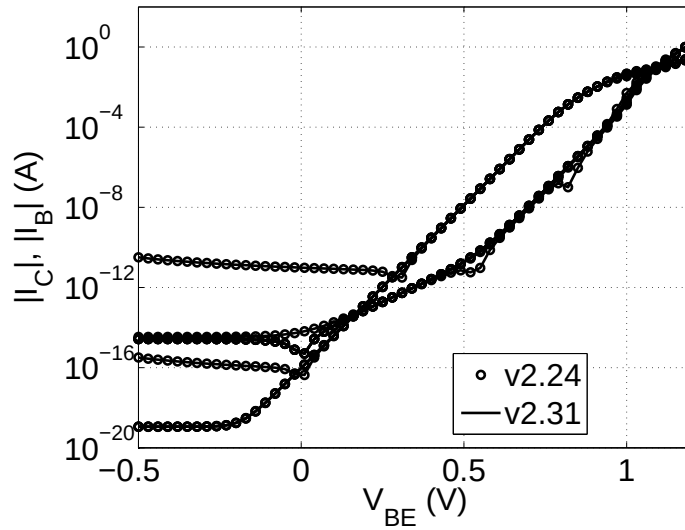


Figure 3.1: Forward gummel at room temperature for $V_{BC} = -0.9...0.3V$

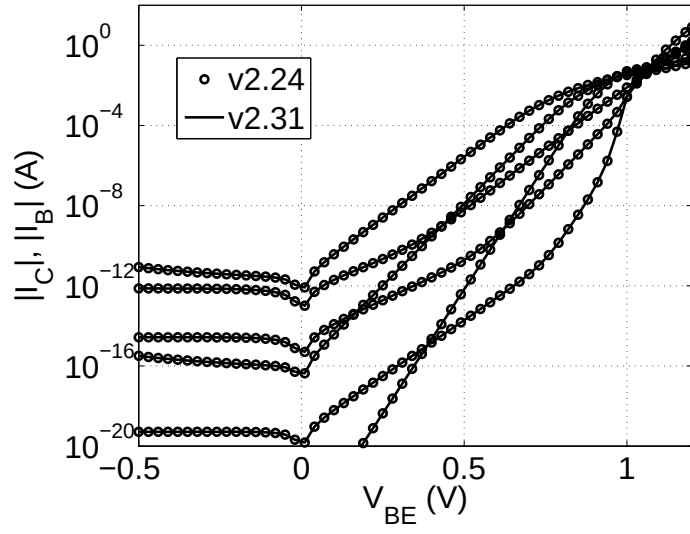


Figure 3.2: Forward gummel at $V_{BC} = 0.0V$ and $T = [200, 300, 400]K$

Reverse gummel

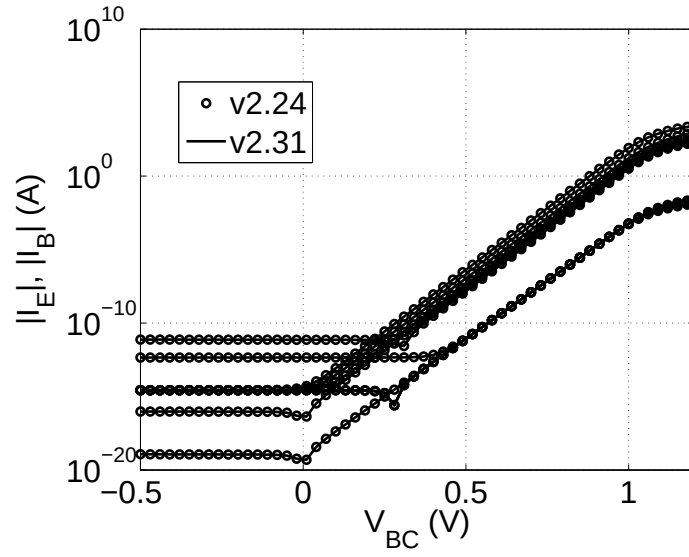


Figure 3.3: Reverse gummel at room temperature for $V_{BE} = -0.9...0.3V$

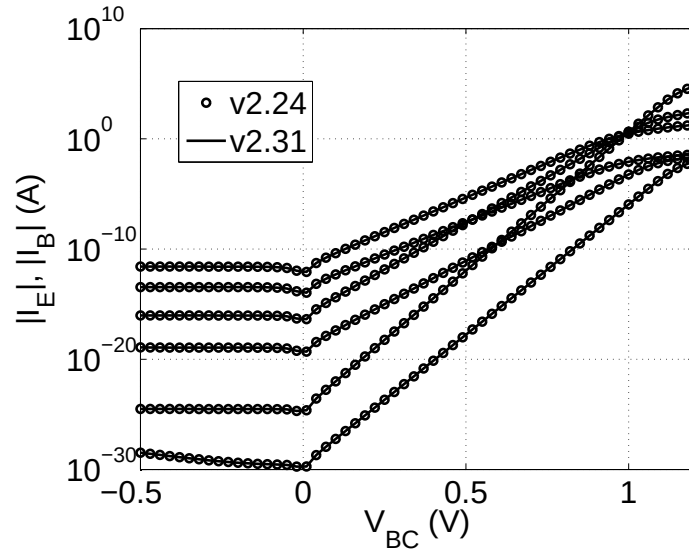
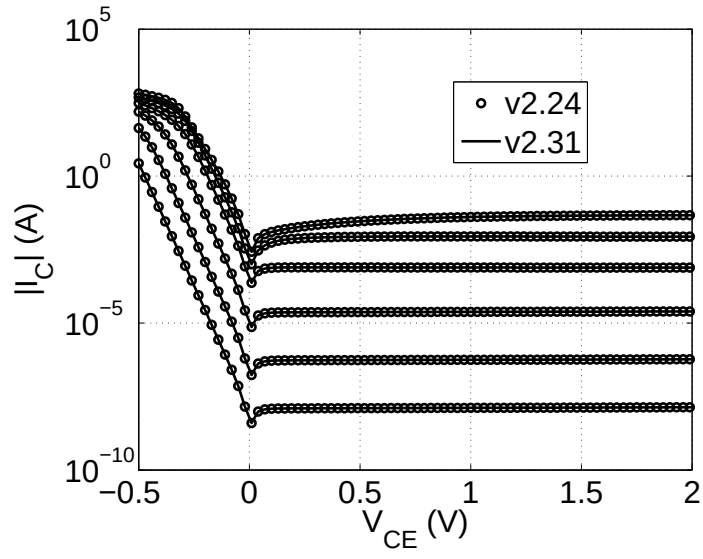
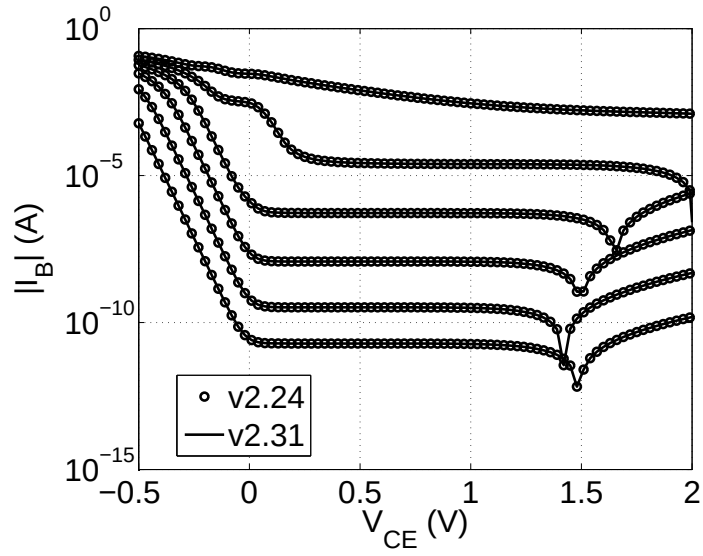


Figure 3.4: Reverse gummel at $V_{BE} = 0.0V$ and $T = [200, 300, 400]K$

Forward output, forced V_{BE} Figure 3.5: Forward output at forced V_{BE} Figure 3.6: Forward output at forced V_{BE}

Forward output, forced I_B

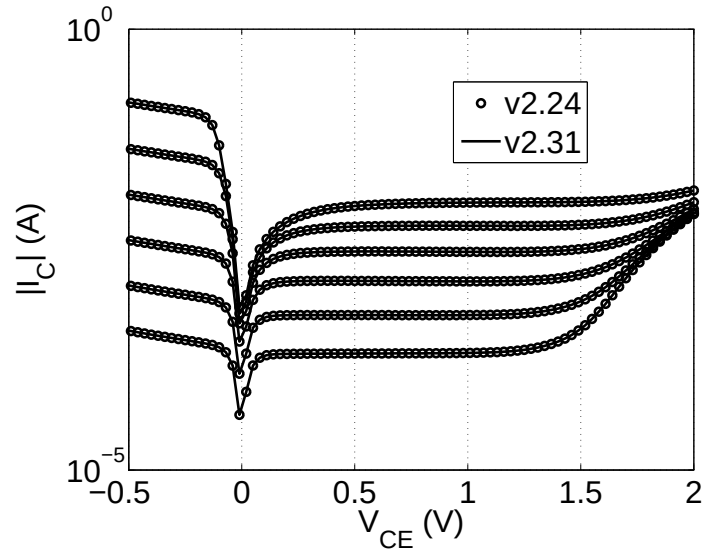


Figure 3.7: Forward output at forced I_B

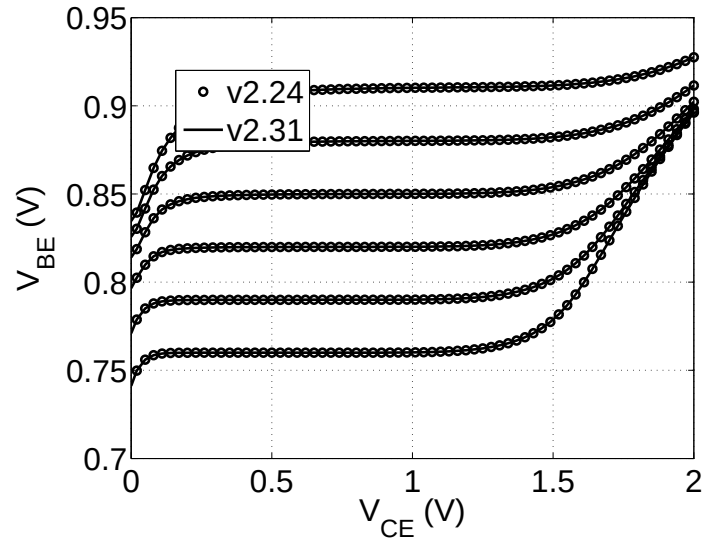


Figure 3.8: Forward output at forced I_B

Small signal results

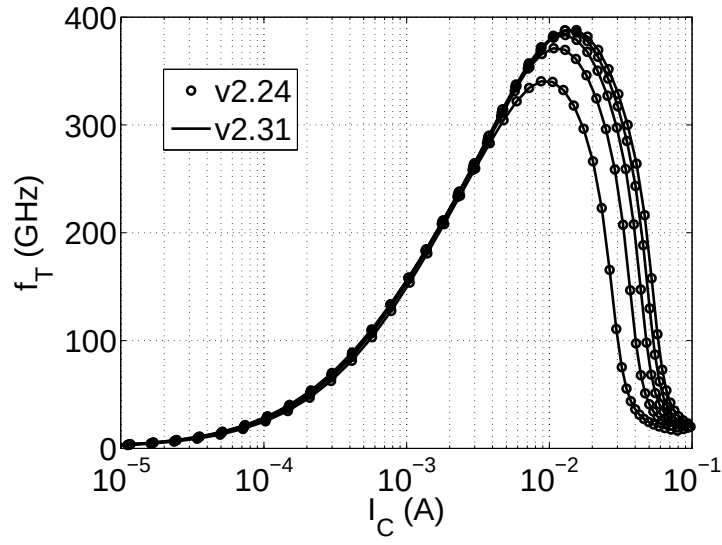


Figure 3.9: Transit frequency versus collector current at room temperature for $V_{BC} = -0.9 \dots 0.3V$

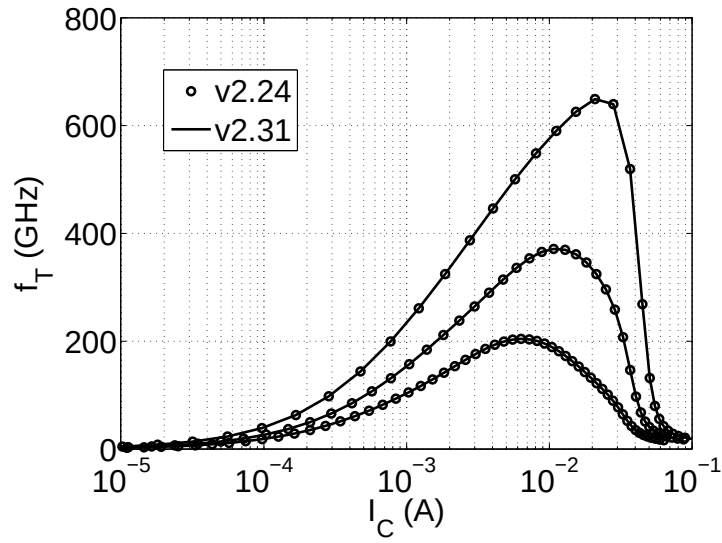


Figure 3.10: Transit frequency versus collector current at $V_{BC} = 0.0V$ and $T = [200, 300, 400]K$

3 Internal transistor, including R_{Bi}

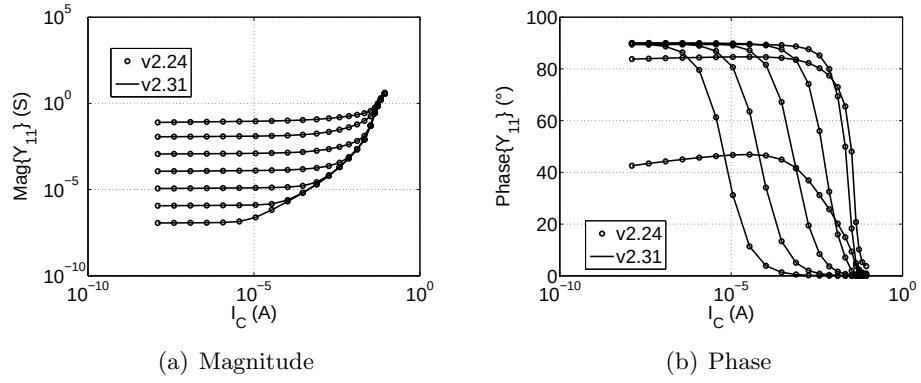


Figure 3.11: Magnitude and phase of Y_{11} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

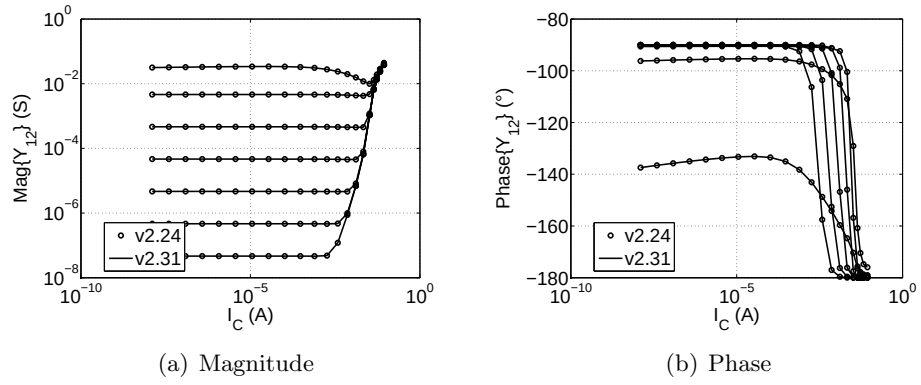


Figure 3.12: Magnitude and phase of Y_{12} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

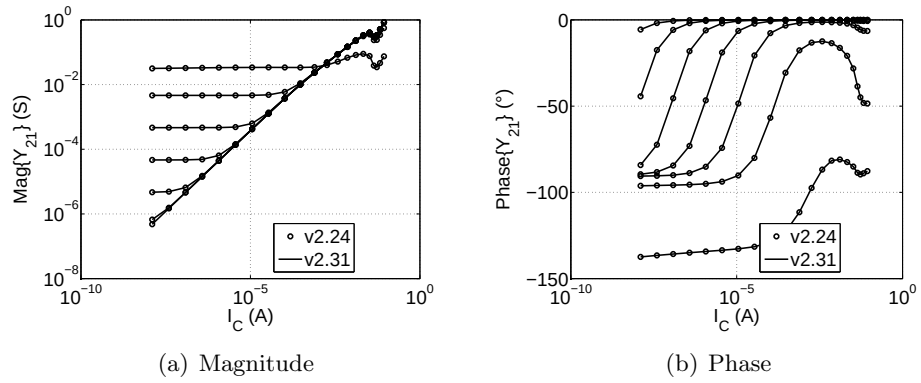


Figure 3.13: Magnitude and phase of Y_{21} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

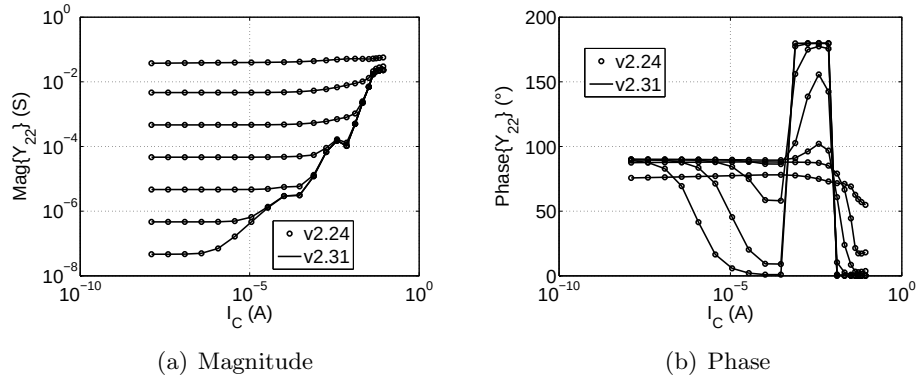


Figure 3.14: Magnitude and phase of Y_{22} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

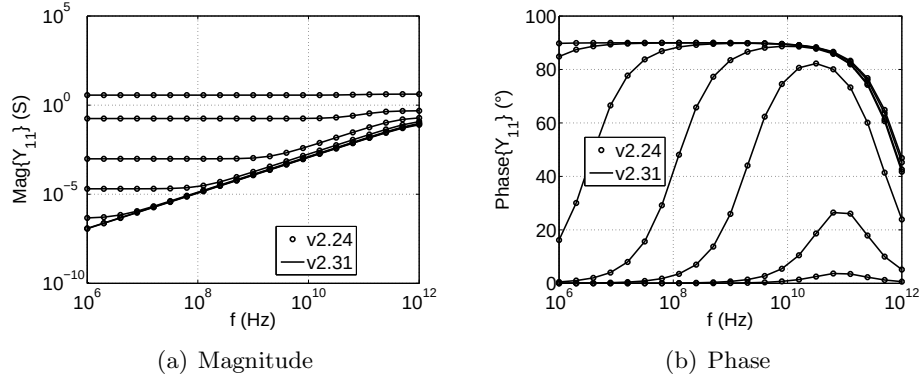


Figure 3.15: Magnitude and phase of Y_{11} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

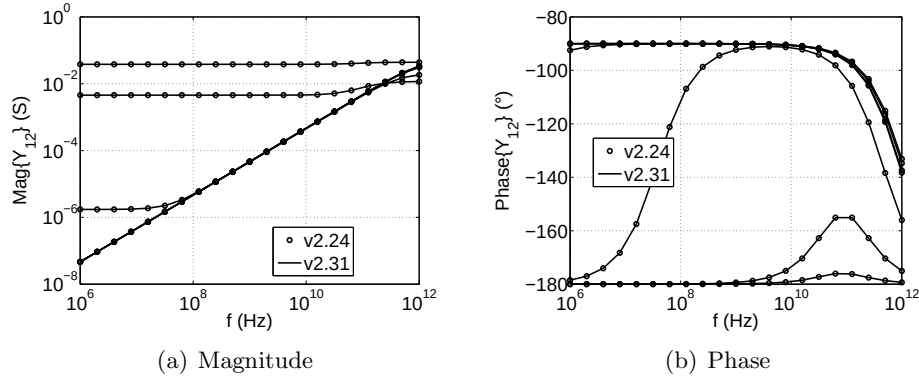


Figure 3.16: Magnitude and phase of Y_{12} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

3 Internal transistor, including R_{Bi}

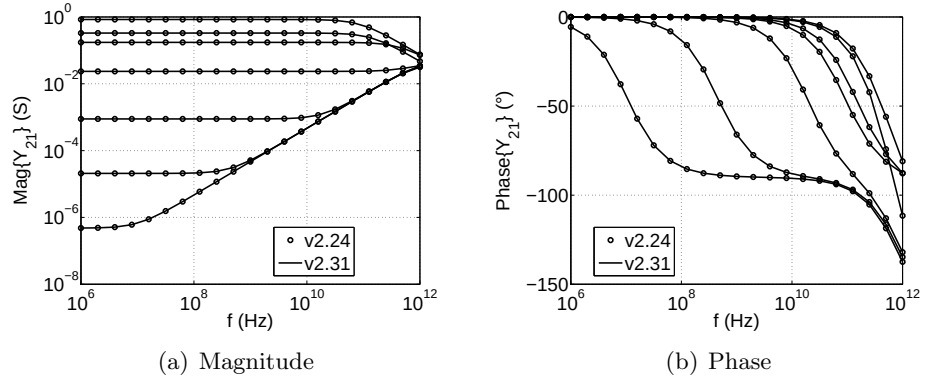


Figure 3.17: Magnitude and phase of Y_{21} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

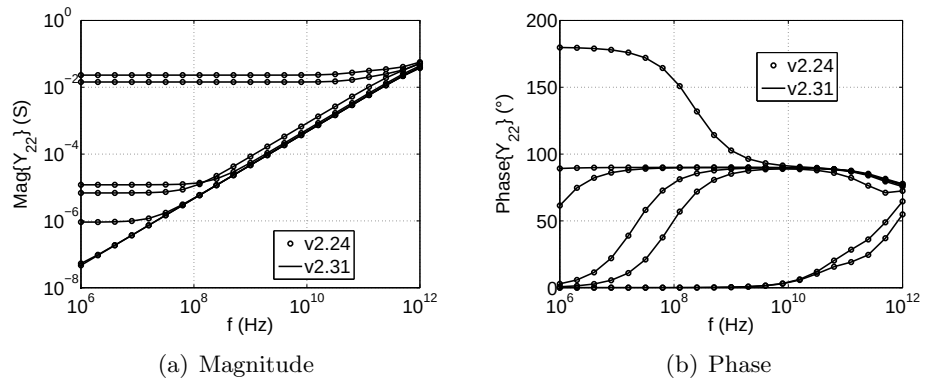


Figure 3.18: Magnitude and phase of Y_{22} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

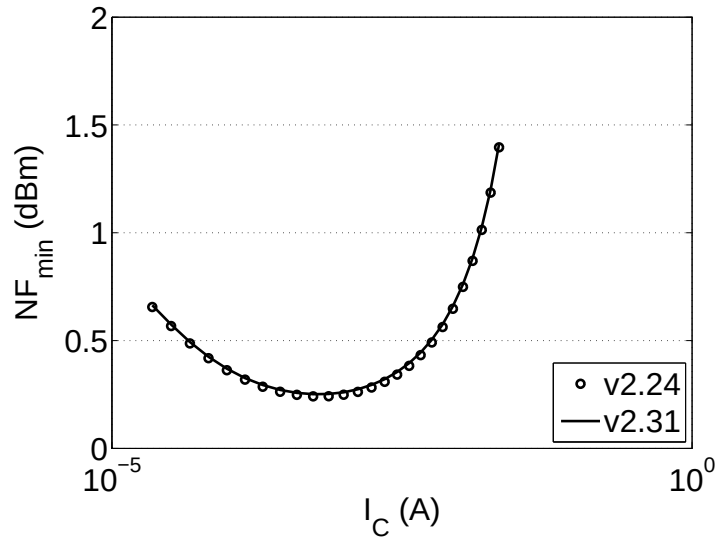
Noise modeling

Figure 3.19: Minimum noise figure versus collector current at room temperature

3.2.2 Comparison between version 2.31 and 2.30**Forward gummel**

3 Internal transistor, including R_{Bi}

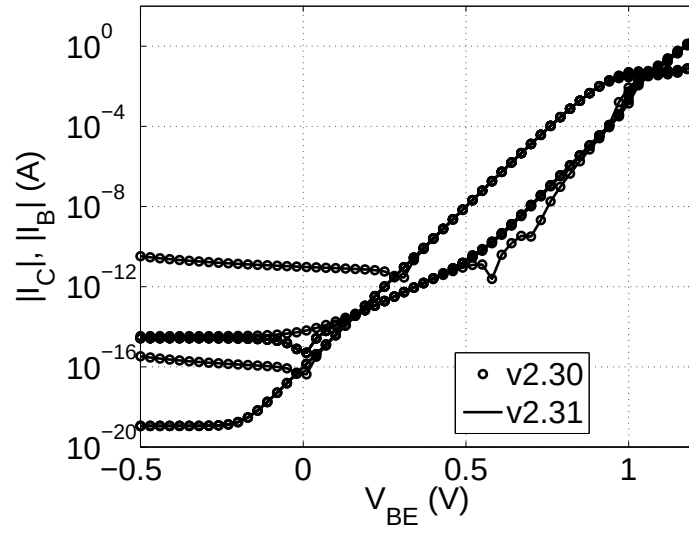


Figure 3.20: Forward gummel at room temperature for $V_{BC} = -0.9...0.3V$

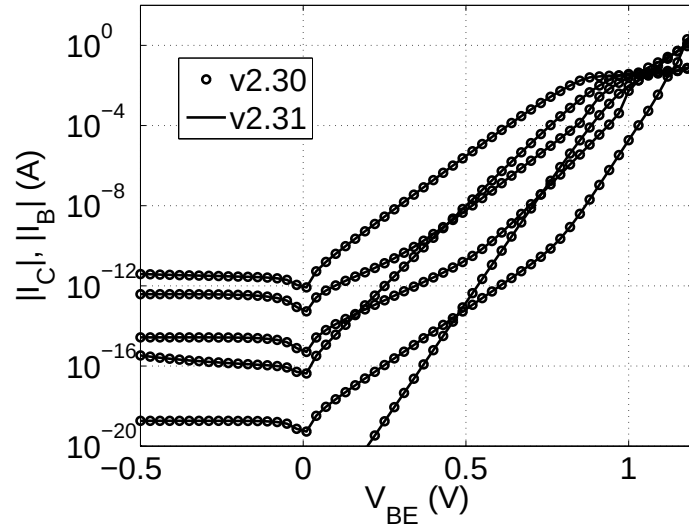
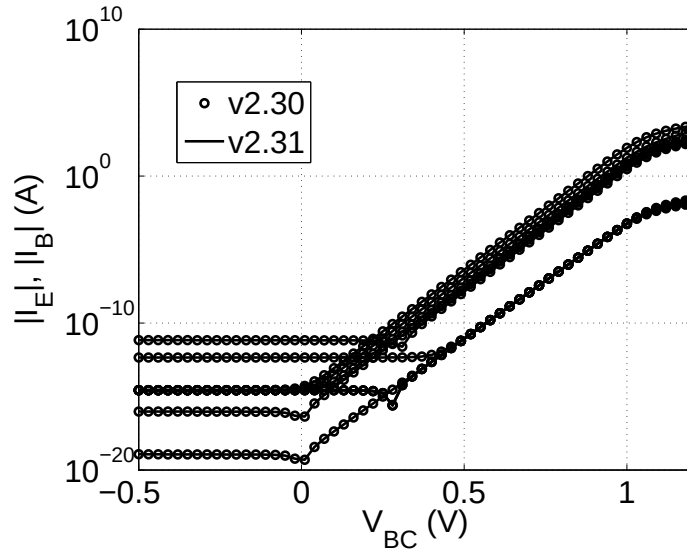
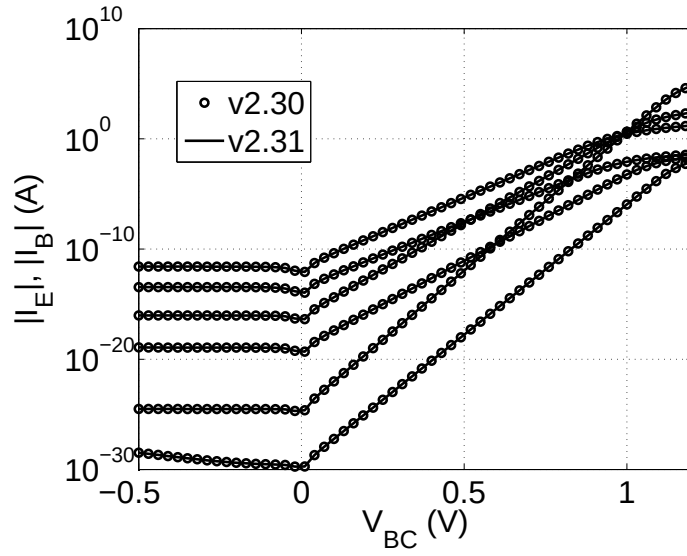


Figure 3.21: Forward gummel at $V_{BC} = 0.0V$ and $T = [200, 300, 400]K$

Reverse gummel

Figure 3.22: Reverse gummel at room temperature for $V_{BE} = -0.9...0.3V$ Figure 3.23: Reverse gummel at $V_{BE} = 0.0V$ and $T = [200, 300, 400]K$

Forward output, forced V_{BE}

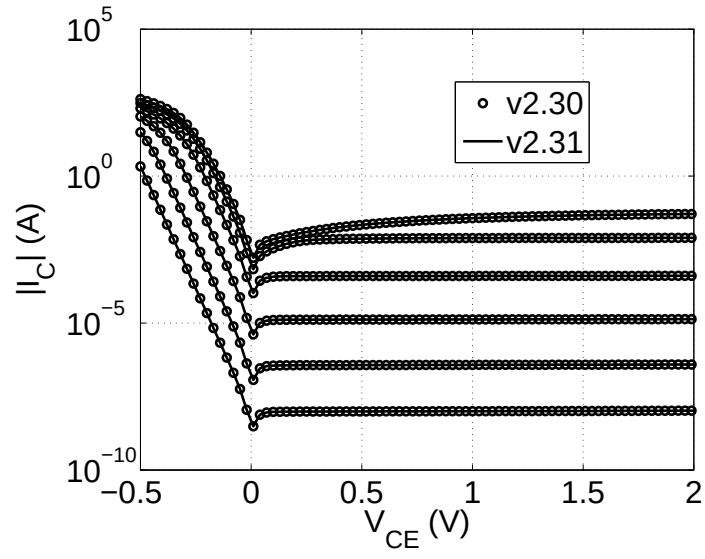


Figure 3.24: Forward output at forced V_{BE}

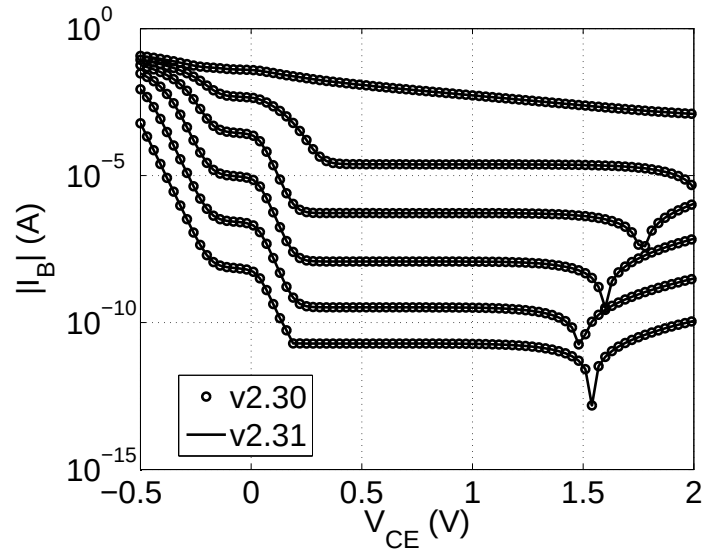
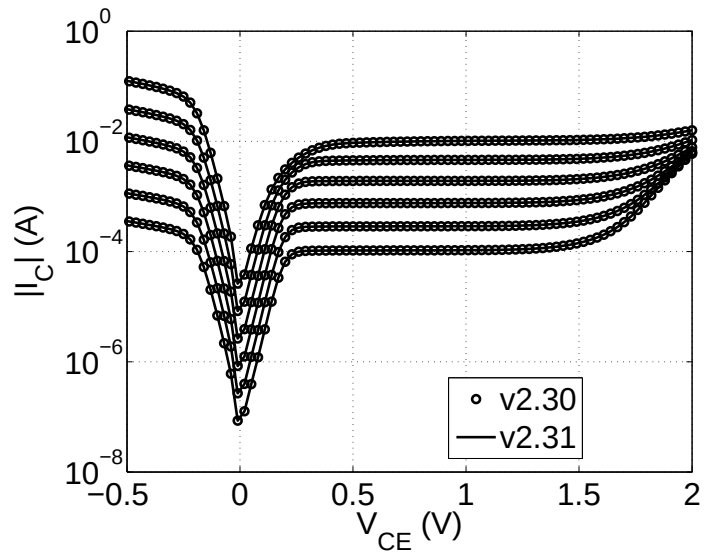
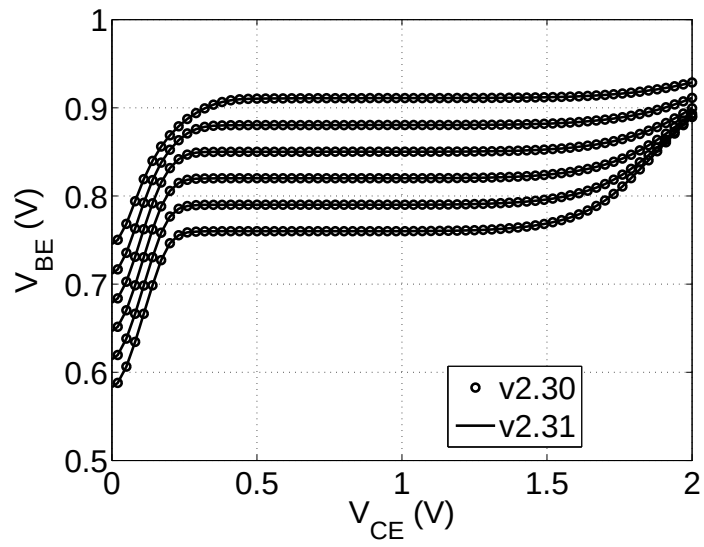


Figure 3.25: Forward output at forced V_{BE}

Forward output, forced I_B Figure 3.26: Forward output at forced I_B Figure 3.27: Forward output at forced I_B

Small signal results

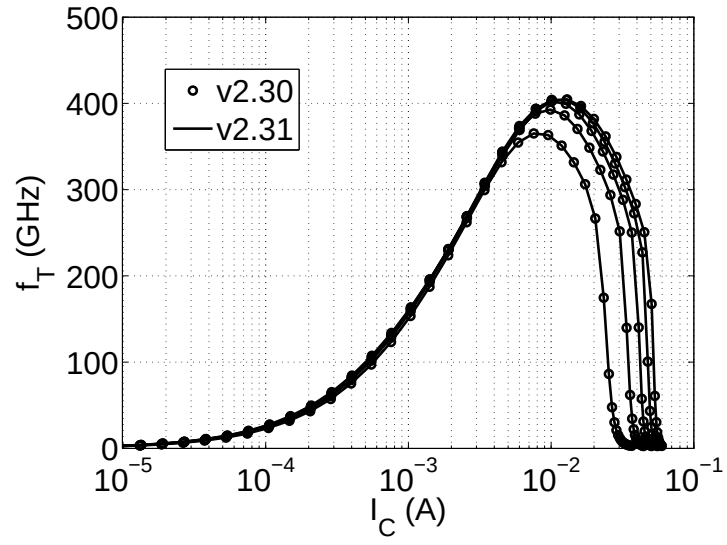


Figure 3.28: Transit frequency versus collector current at room temperature for $V_{BC} = -0.9...0.3V$

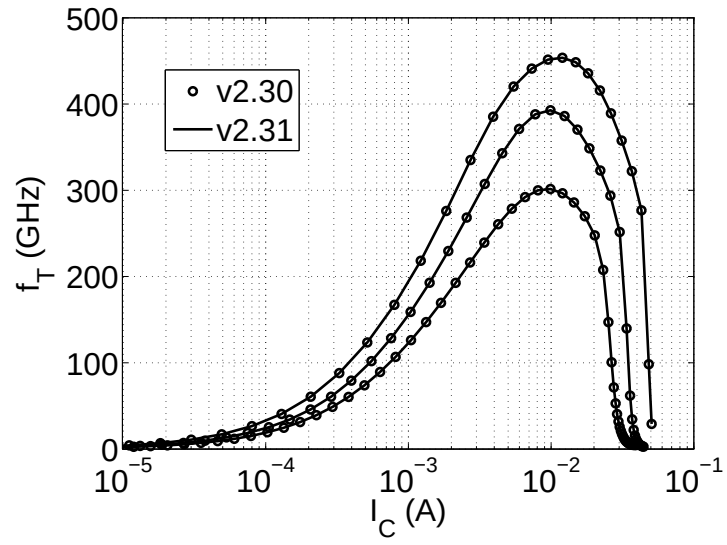


Figure 3.29: Transit frequency versus collector current at $V_{BC} = 0.0V$ and $T = [200, 300, 400]K$

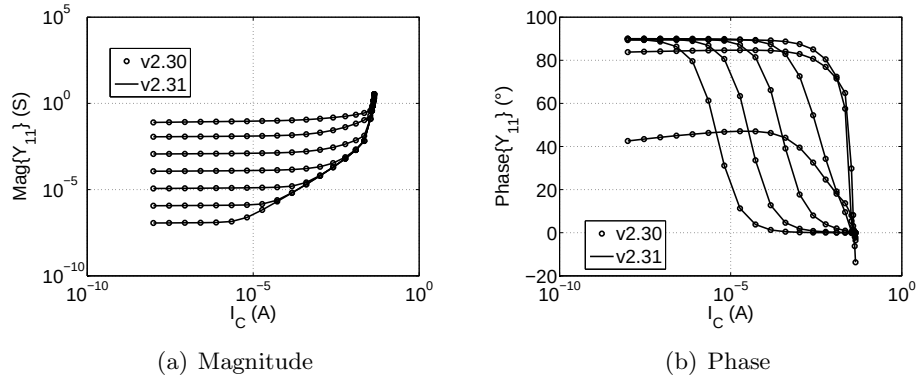


Figure 3.30: Magnitude and phase of Y_{11} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

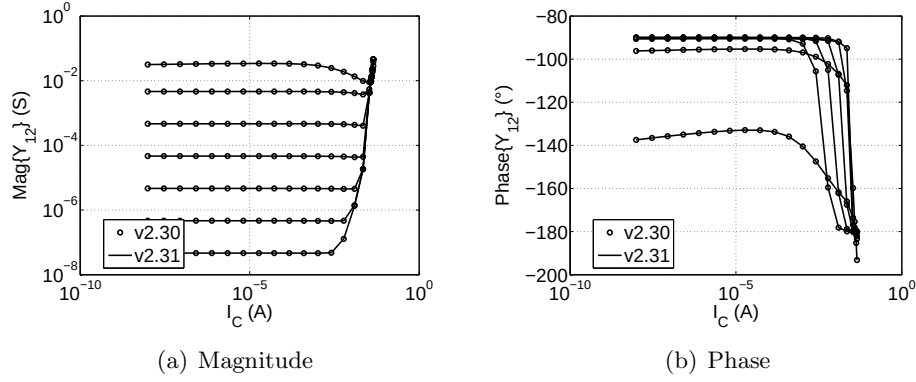


Figure 3.31: Magnitude and phase of Y_{12} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

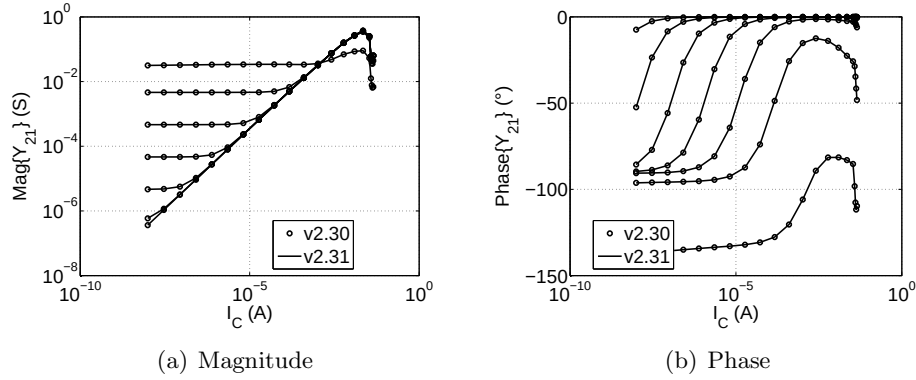


Figure 3.32: Magnitude and phase of Y_{21} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

3 Internal transistor, including R_{Bi}

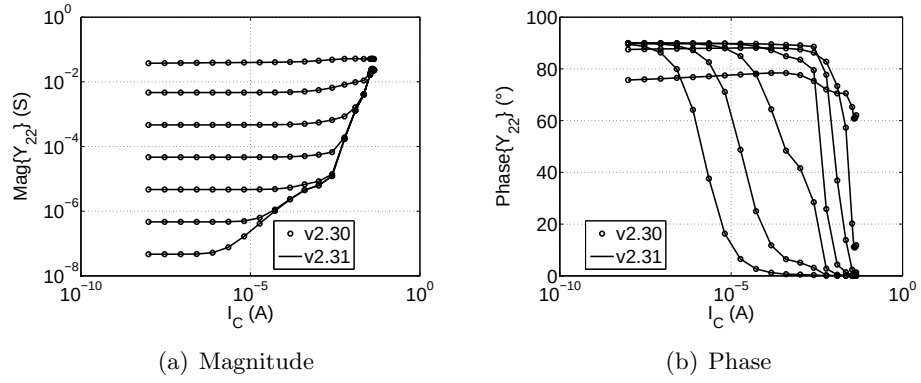


Figure 3.33: Magnitude and phase of Y_{22} versus collector current for $f=1\text{ MHz} \dots 1\text{ THz}$ at $V_{BC} = 0.0V$ and room temperature

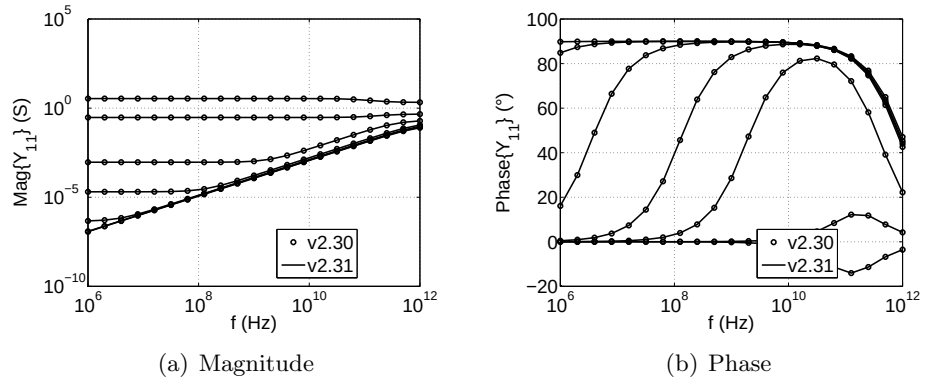


Figure 3.34: Magnitude and phase of Y_{11} versus frequency for $V_{BE} = 0.5 \dots 1.1V$ at $V_{BC} = 0.0V$ and room temperature

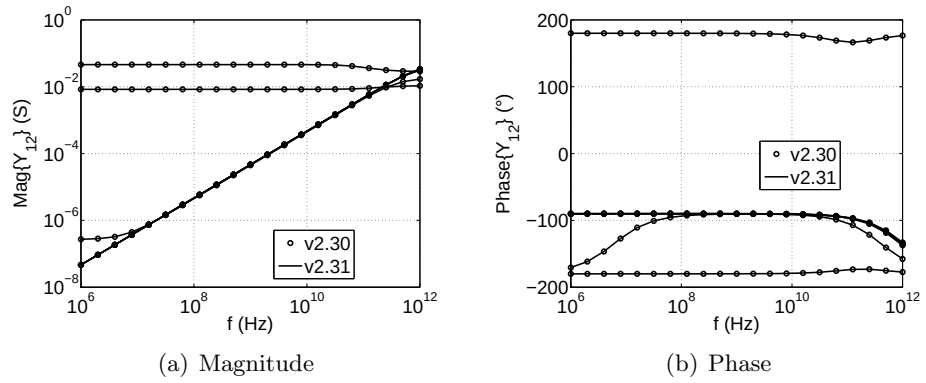


Figure 3.35: Magnitude and phase of Y_{12} versus frequency for $V_{BE} = 0.5 \dots 1.1V$ at $V_{BC} = 0.0V$ and room temperature

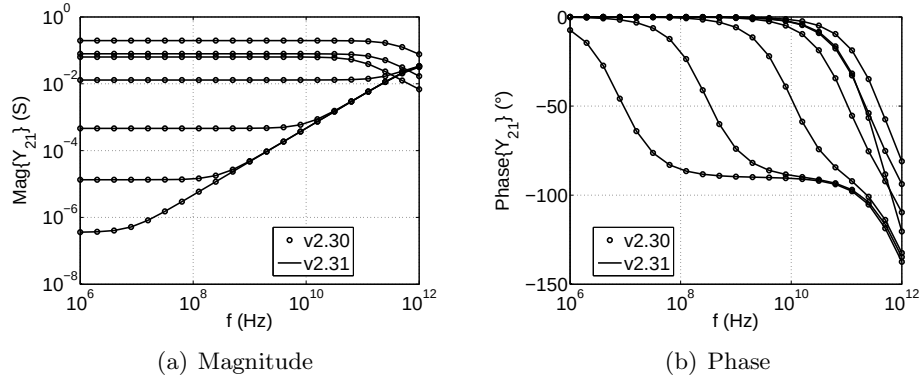


Figure 3.36: Magnitude and phase of Y_{21} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

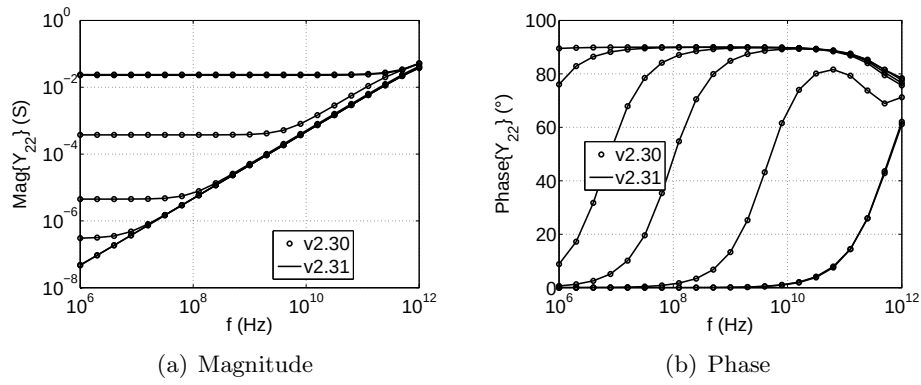


Figure 3.37: Magnitude and phase of Y_{22} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

Noise modeling

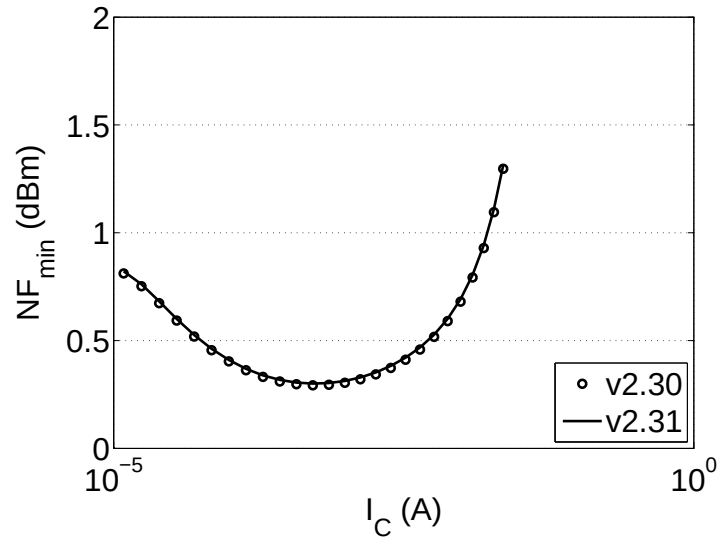


Figure 3.38: Minimum noise figure versus collector current at room temperature

4 Complete transistor

4.1 Model cards

4.1.1 Version 2.31, compatible to 2.24

```
c10=2.0175e-032 qp0=2.155e-016 ich=0 hfe=1.8331
hfc=0.05 hjei=0.034883 hjci=0.0026778 ibeis=1.41e-020
mbei=1.012 ireis=1.3583e-015 mrei=2.263 ibeps=1.41e-020
mbep=1.012 ireps=1.3583e-015 mrep=2.263 mcf=1 tbhrec=1e-012
ibcis=5.825e-020 mbci=1.066 ibcx=5.825e-020 mbcx=1.066
ibets=1e-014 abet=40 tunode=1 favl=240.3 qavl=1.1756e-013
alfav=-0.009966 alqav=-0.0009569 rbi0=25 rbx=11 fgeo=0.6557
fdqr0=13 fcrbi=0 fqi=1 re=2.503 rcx=10.55 itss=0 msf=1
iscs=0 msc=1 tsf=0 rsu=0 csu=0 cjei0=4.6632e-015
vdei=0.87043 zei=0.20065 ajei=2.1953 cjep0=4.6632e-015
vdep=0.87043 zep=0.20065 ajep=2.1953 cjci0=3.7096e-015
vdci=0.73351 zci=0.36198 vptci=3.2461 cjcx0=0 vdcx=0.7 zcx=0.4
vptcx=100 fbcpar=0 fbepar=1 cjs0=7.06e-015 vds=0.6 zs=0.17
vpts=100 t0=2.2784e-013 dt0h=1.0591e-013 tbvl=1.5456e-014
tef0=4.4727e-013 gtfe=1.4744 thcs=1e-011 ahc=0.06 fthc=0.5
rci0=19.44 vlim=1.429 vces=0.001 vpt=18 tr=0
cbepar=3.81e-015 cbcpar=4.86e-015 alqf=0.16667 alit=0.33333
flnqs=0 kf=0 af=2 cfbe=-1 latb=0 latl=0 vgb=0.9
alt0=0.0025354 kt0=1e-005 zetaci=0.5621 alvs=0.00217
alces=-0.00584 zetarbi=0 zetarbx=0 zetarcx=0.191 zetare=0.2042
zetacx=-3.2 vge=1.17 vgc=1.17 vgs=1.17 flvg=-0.00010238
f2vg=0.00043215 zetact=5.3125 zetabet=1.3855 alb=0 flsh=0 rth=0
cth=0 flcomp=2.2 tnom=27 dt=0 zetarth=0 type=1 flcono=0
```

4.1.2 Version 2.31, compatible to 2.30

```
c10=2.0175e-032 qp0=2.155e-016 ich=0 hfe=1.8331
hfc=0.05 hjei=0.034883 hjci=0.0026778 ibeis=1.41e-020
mbei=1.012 ireis=1.3583e-015 mrei=2.263 ibeps=1.41e-020
mbep=1.012 ireps=1.3583e-015 mrep=2.263 mcf=1 tbhrec=1e-012
ibcis=5.825e-020 mbci=1.066 ibcx=5.825e-020 mbcx=1.066
ibets=1e-014 abet=40 tunode=1 favl=240.3 qavl=1.1756e-013
alfav=-0.009966 alqav=-0.0009569 rbi0=25 rbx=11 fgeo=0.6557
```

4 Complete transistor

```
fdqr0=13 fcrbi=0 fqi=1 re=2.503 rcx=10.55 itss=0 msf=1
iscs=0 msc=1 tsf=0 rsu=0 csu=0 cjei0=4.6632e-015
vdei=0.87043 zei=0.20065 ajei=2.1953 cjep0=4.6632e-015
vdep=0.87043 zep=0.20065 ajep=2.1953 cjci0=3.7096e-015
vdci=0.73351 zci=0.36198 vptci=3.2461 cjc0=0 vdcx=0.7 zcx=0.4
vptcx=100 fbcpar=0 fbepar=1 cjs0=7.06e-015 vds=0.6 zs=0.17
vpts=100 t0=2.2784e-013 dt0h=1.0591e-013 tbvl=1.5456e-014
tef0=4.4727e-013 gtfe=1.4744 thcs=1e-011 ahc=0.06 fthc=0.5
rci0=19.44 vlim=1.429 vces=0.001 vpt=18 tr=0
cbepar=3.81e-015 cbcpar=4.86e-015 alqf=0.16667 alit=0.33333
flnqs=0 kf=0 af=2 cfbe=-1 latb=0 latl=0 vgb=0.9
alt0=0.0025354 kt0=1e-005 zetaci=0.5621 alvs=0.00217
alces=-0.00584 zetarbi=0 zetarbx=0 zetarcx=0.191 zetare=0.2042
zetacx=-3.2 vge=1.17 vgc=1.17 vgs=1.17 flvg=-0.00010238
f2vg=0.00043215 zetact=5.3125 zetabet=1.3855 alb=0 flsh=0 rth=0
cth=0 flcomp=2.3 tnom=27 dt=0 zetarh=0 type=1 flcono=0
hf0=0.24679 ahjei=5.912 rhjei=2 vcbar=0.04 icbar=0.003
acbar=1.5 delck=1.8 dvgbe=-0.1103 zetaahjei=-0.78133
zetavgbe=0.7 alrth=0
```

4.2 Simulation results

4.2.1 Comparison between version 2.31 and 2.24

Forward gummel

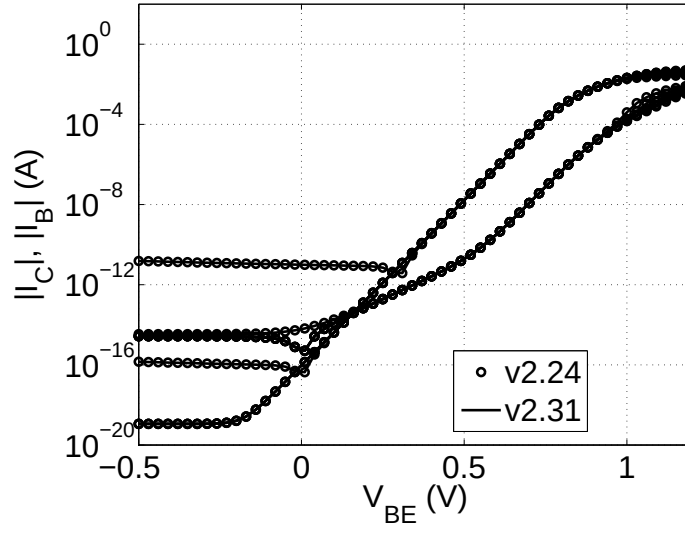


Figure 4.1: Forward gummel at room temperature for $V_{BC} = -0.9...0.3V$

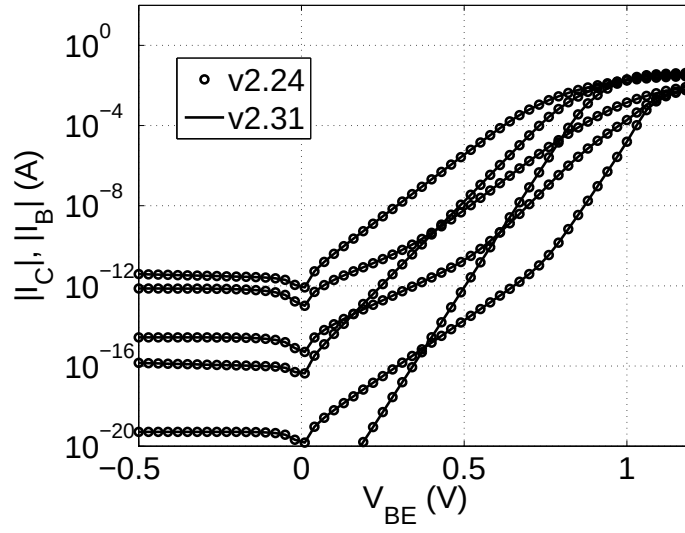


Figure 4.2: Forward gummel at $V_{BC} = 0.0V$ and $T = [200, 300, 400]K$

Reverse gummel

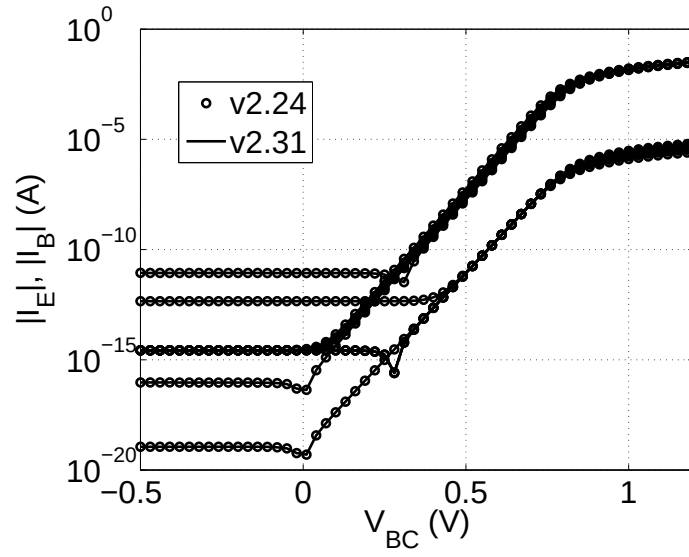


Figure 4.3: Reverse gummel at room temperature for $V_{BE} = -0.9...0.3V$

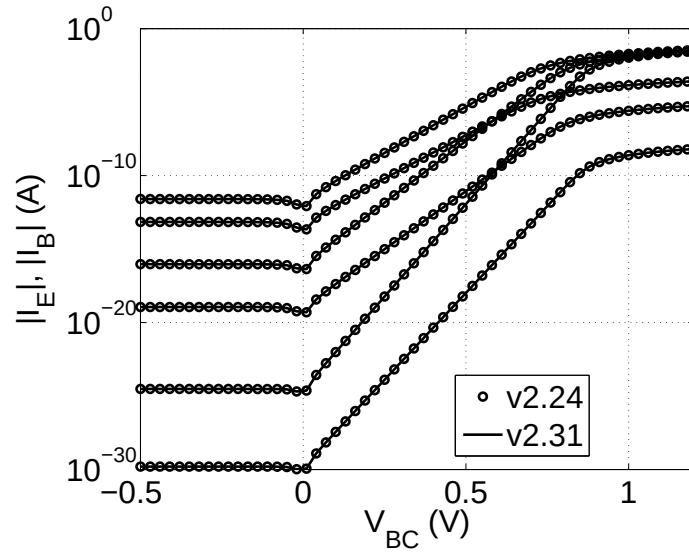
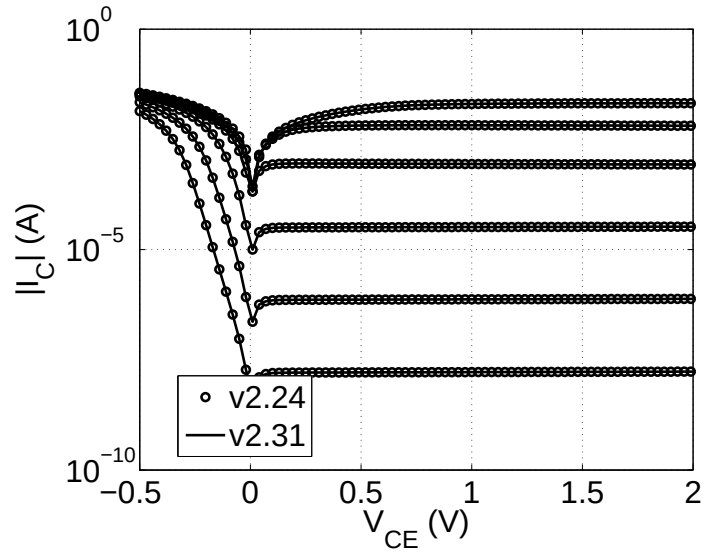
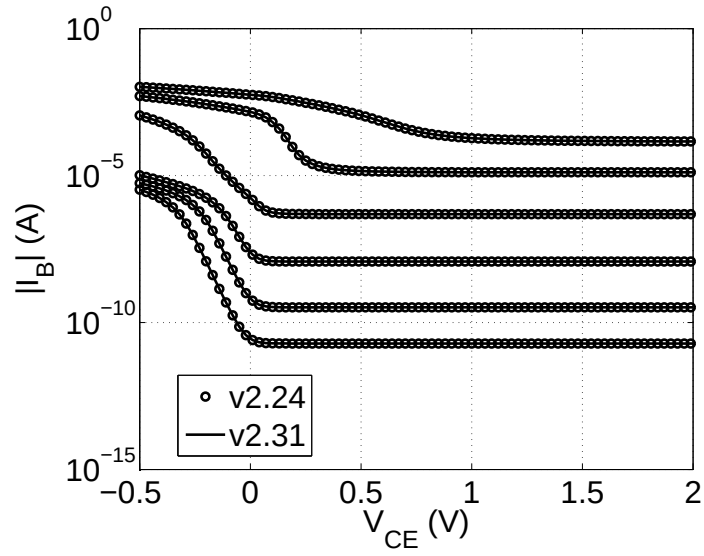


Figure 4.4: Reverse gummel at $V_{BE} = 0.0V$ and $T = [200, 300, 400]K$

Forward output, forced V_{BE} Figure 4.5: Forward output at forced V_{BE} Figure 4.6: Forward output at forced V_{BE}

Forward output, forced I_B

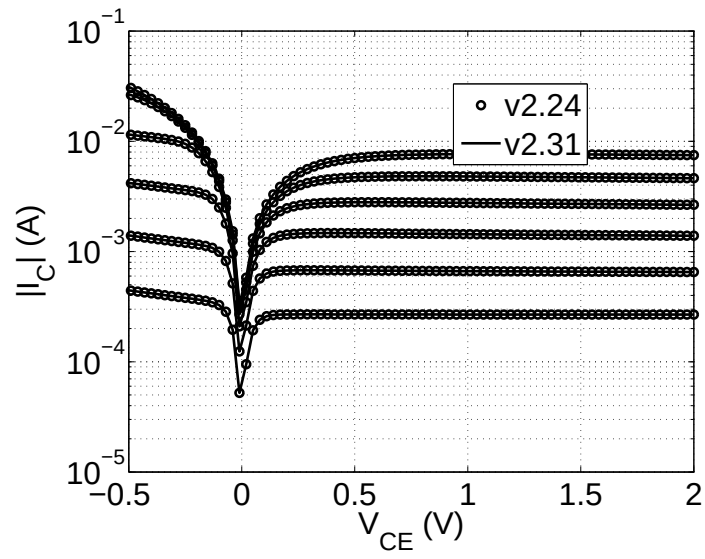


Figure 4.7: Forward output at forced I_B

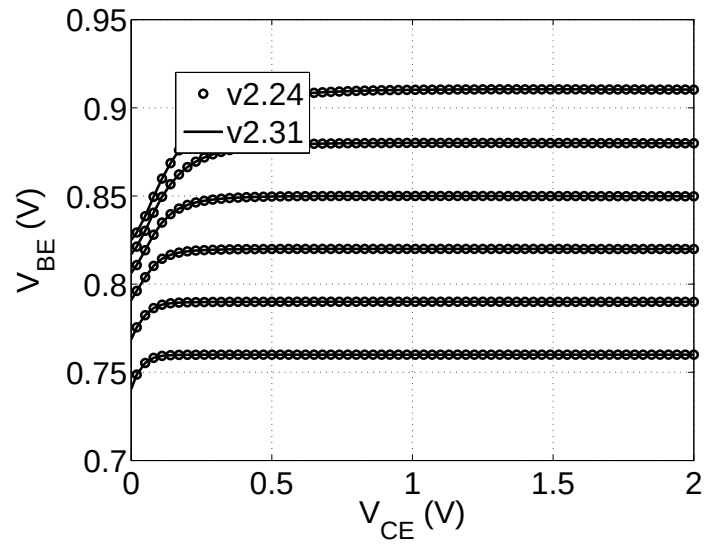


Figure 4.8: Forward output at forced I_B

Small signal results

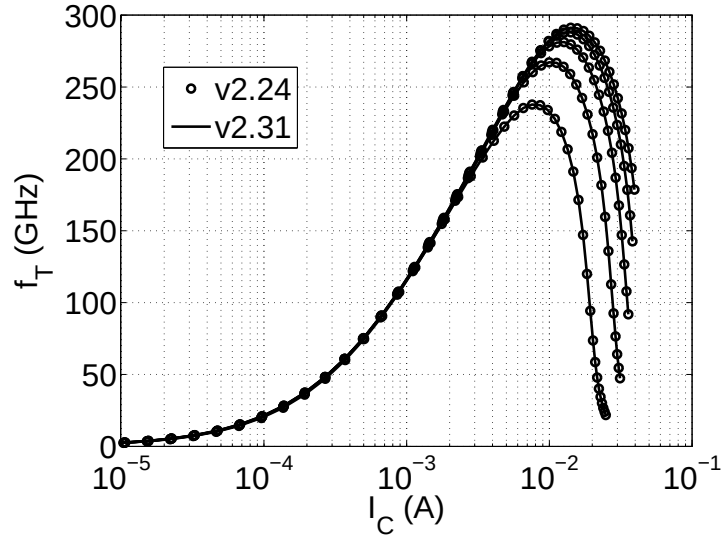


Figure 4.9: Transit frequency versus collector current at room temperature for $V_{BC} = -0.9 \dots 0.3V$

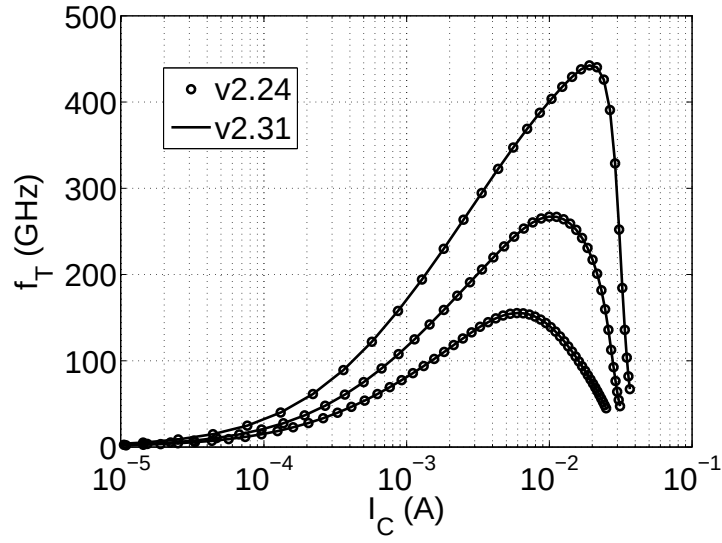


Figure 4.10: Transit frequency versus collector current at $V_{BC} = 0.0V$ and $T = [200, 300, 400]K$

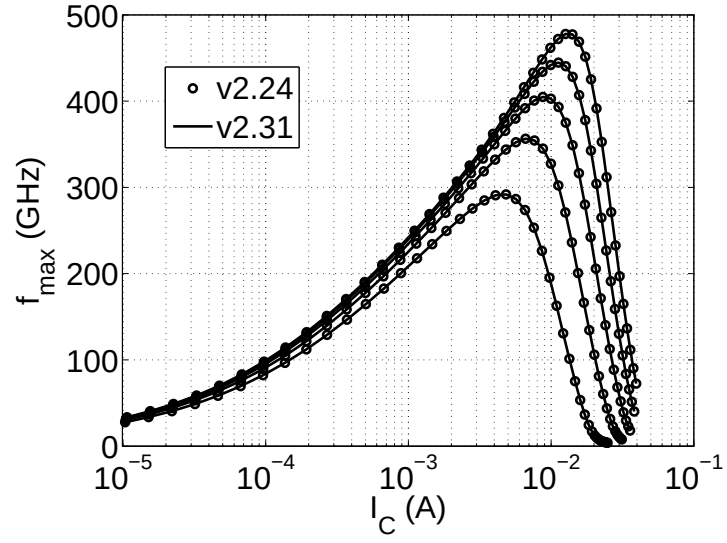


Figure 4.11: Maximum oscillation frequency versus collector current at room temperature for $V_{BC} = -0.9...0.3V$

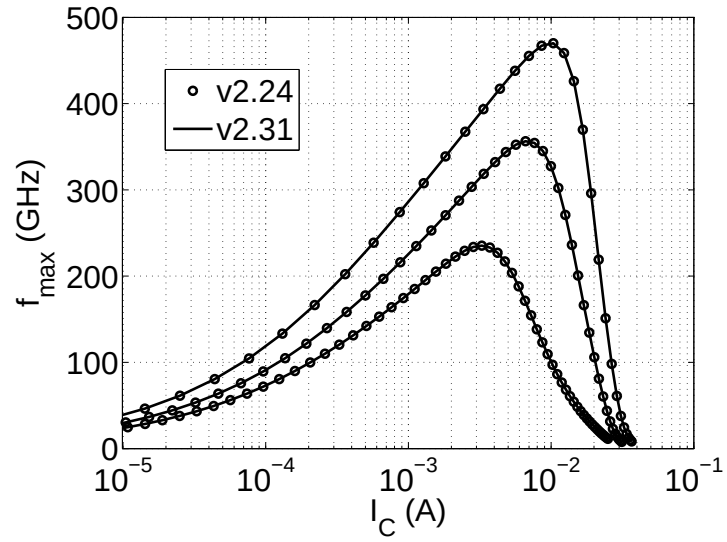


Figure 4.12: Maximum oscillation frequency versus collector current at $V_{BC} = 0.0V$ and $T = [200, 300, 400]K$

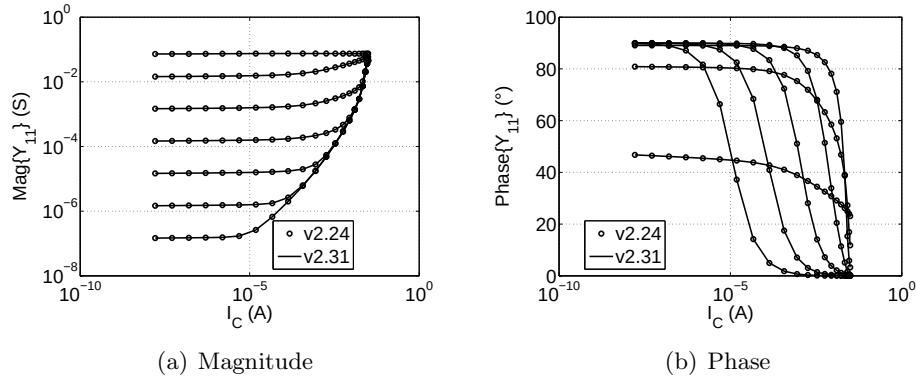


Figure 4.13: Magnitude and phase of Y_{11} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

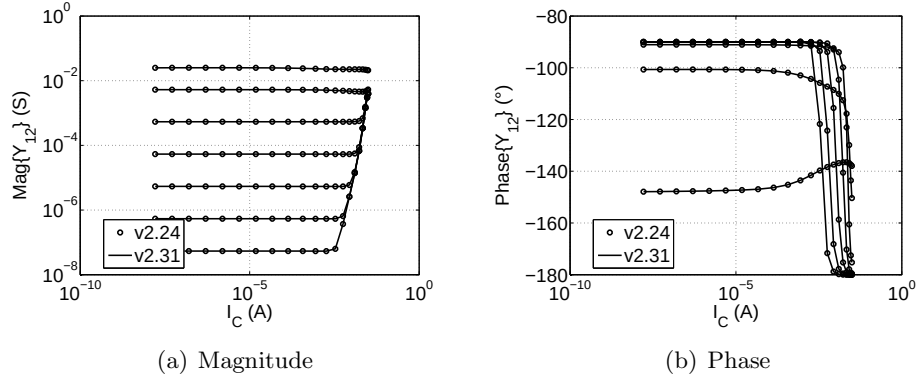


Figure 4.14: Magnitude and phase of Y_{12} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

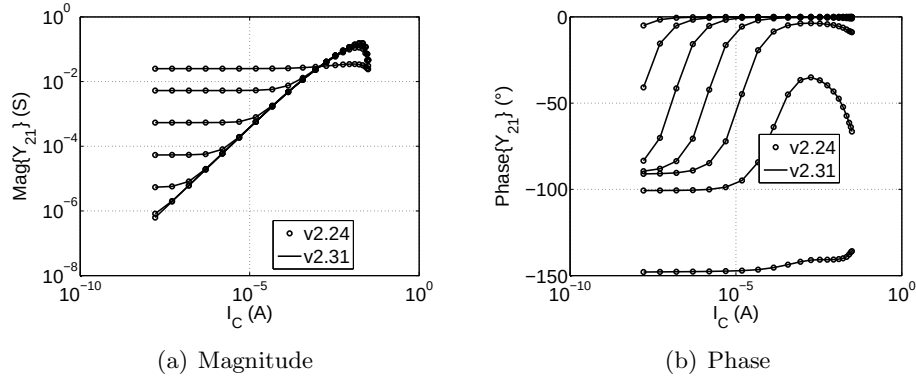


Figure 4.15: Magnitude and phase of Y_{21} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

4 Complete transistor

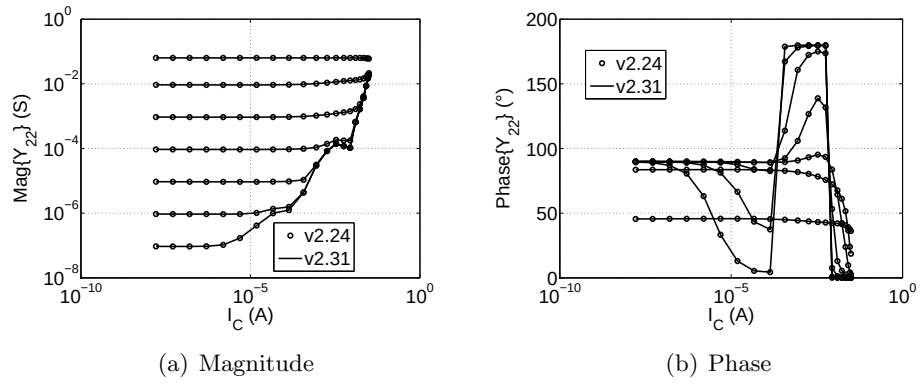


Figure 4.16: Magnitude and phase of Y_{22} versus collector current for $f=1\text{ MHz}\dots 1\text{ THz}$ at $V_{BC} = 0.0V$ and room temperature

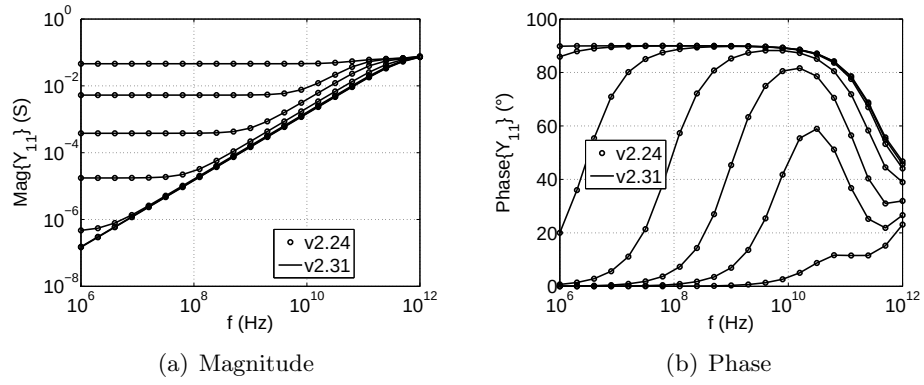


Figure 4.17: Magnitude and phase of Y_{11} versus frequency for $V_{BE} = 0.5\dots 1.1V$ at $V_{BC} = 0.0V$ and room temperature

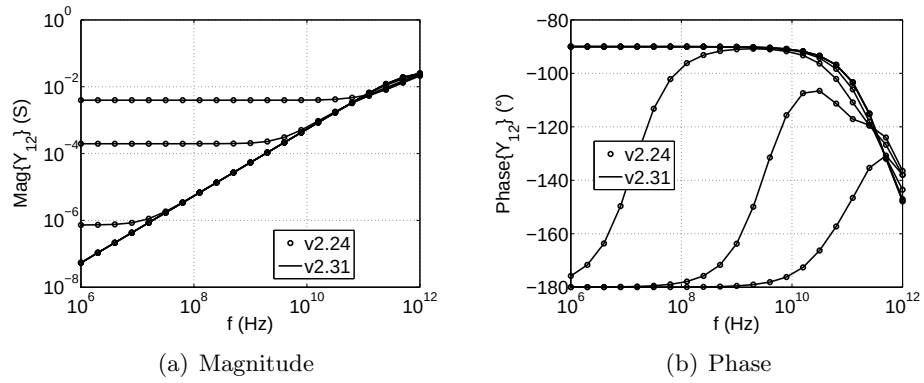


Figure 4.18: Magnitude and phase of Y_{12} versus frequency for $V_{BE} = 0.5\dots 1.1V$ at $V_{BC} = 0.0V$ and room temperature

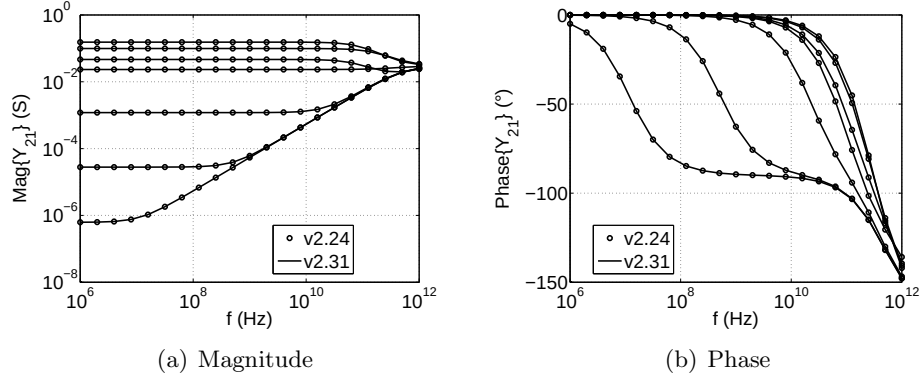


Figure 4.19: Magnitude and phase of Y_{21} versus frequency for $V_{BE} = 0.5 \dots 1.1V$ at $V_{BC} = 0.0V$ and room temperature

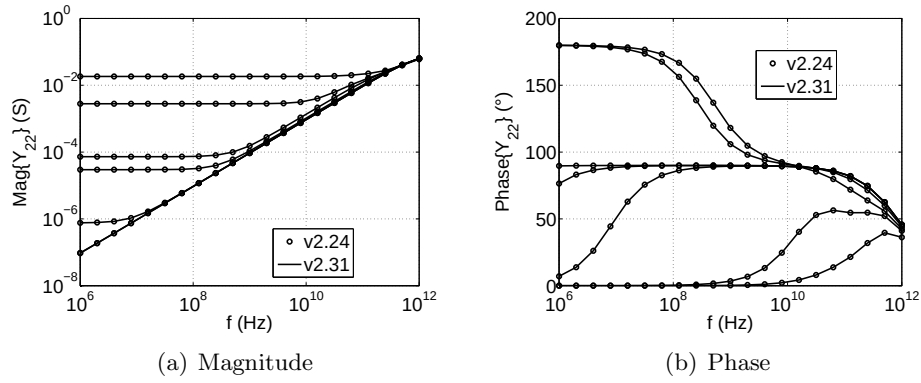


Figure 4.20: Magnitude and phase of Y_{22} versus frequency for $V_{BE} = 0.5 \dots 1.1V$ at $V_{BC} = 0.0V$ and room temperature

Noise modeling

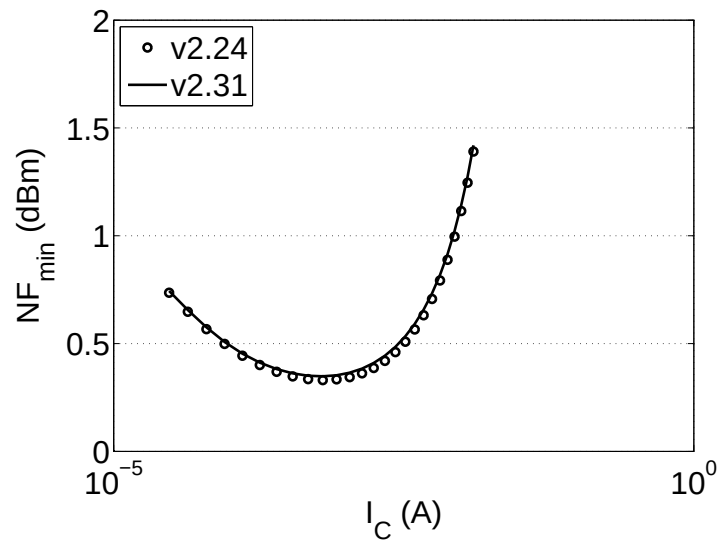
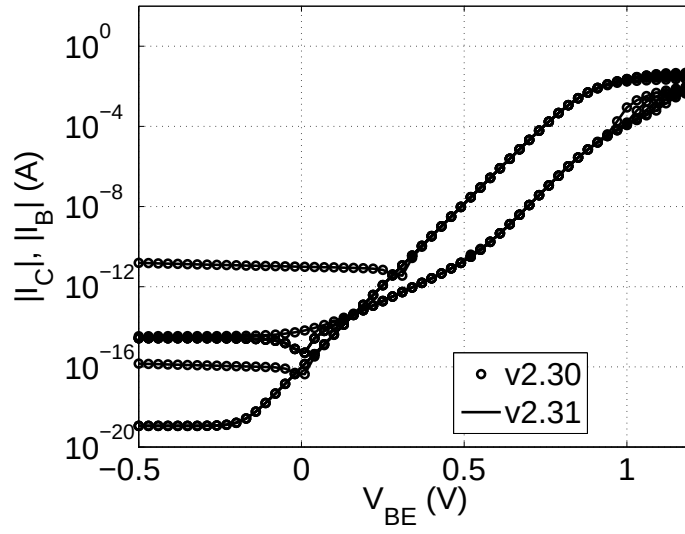
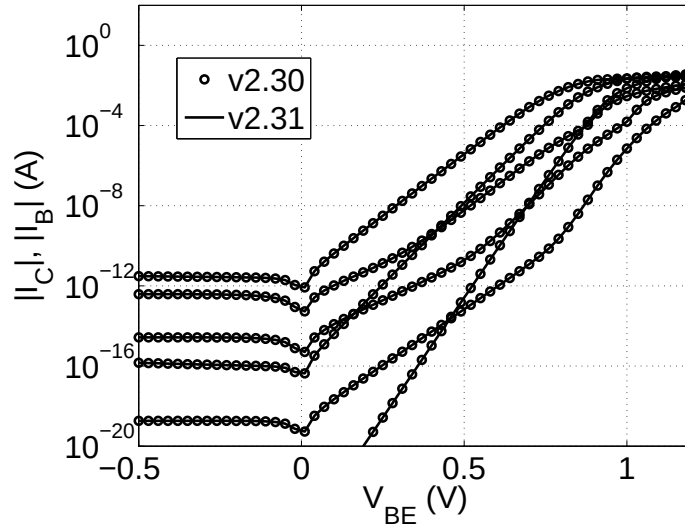


Figure 4.21: Minimum noise figure versus collector current at room temperature

4.2.2 Comparison between version 2.31 and 2.30

Forward gummel

Figure 4.22: Forward gummel at room temperature for $V_{BC} = -0.9...0.3V$ Figure 4.23: Forward gummel at $V_{BC} = 0.0V$ and $T = [200, 300, 400]K$

Reverse gummel

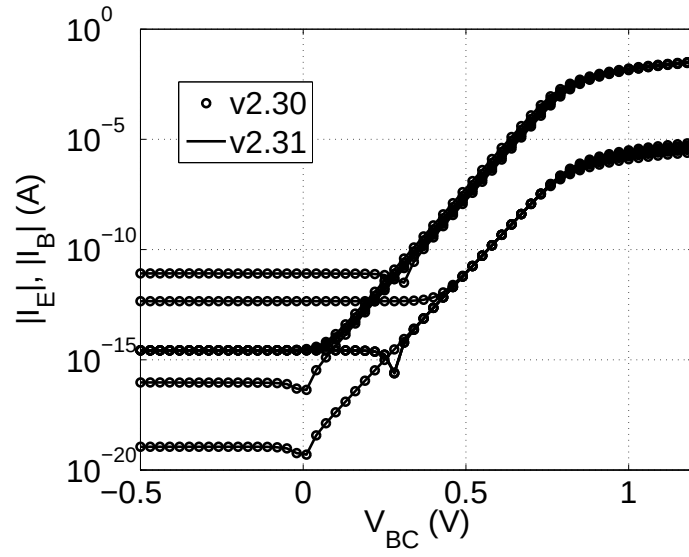


Figure 4.24: Reverse gummel at room temperature for $V_{BE} = -0.9...0.3V$

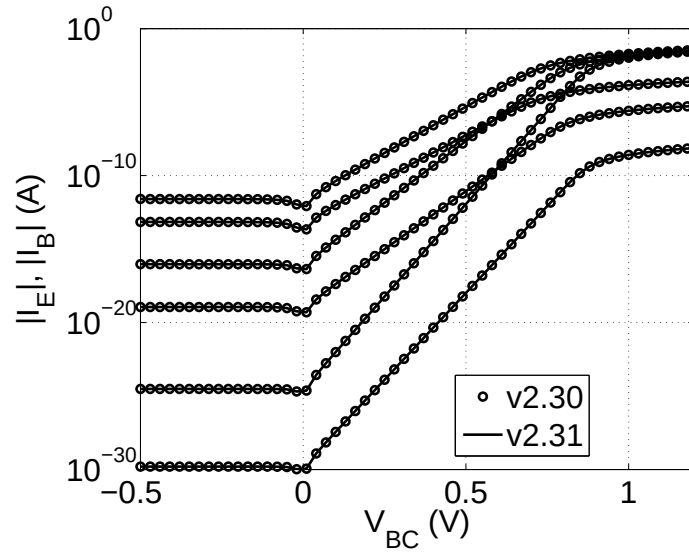
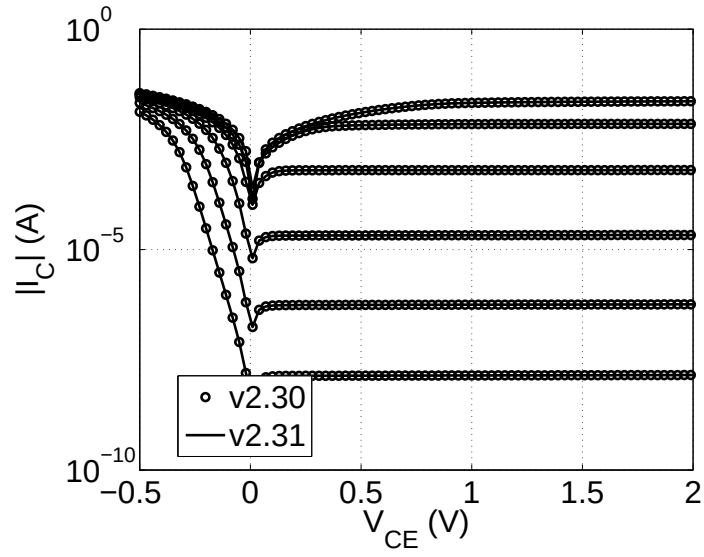
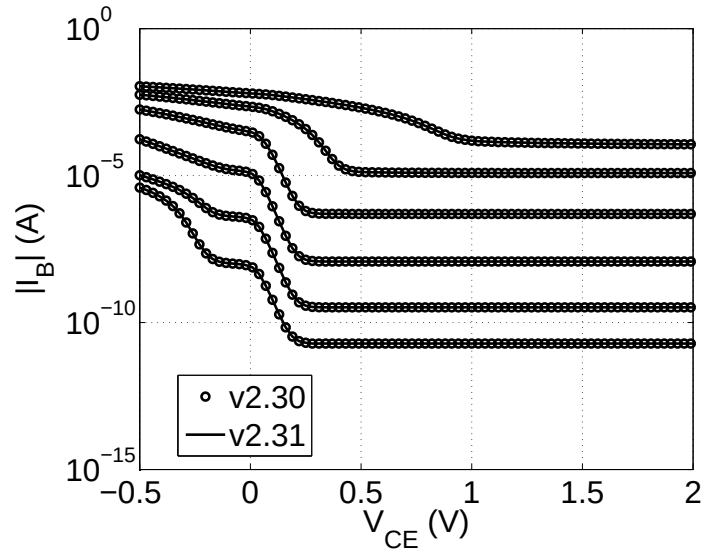


Figure 4.25: Reverse gummel at $V_{BE} = 0.0V$ and $T = [200, 300, 400]K$

Forward output, forced V_{BE} Figure 4.26: Forward output at forced V_{BE} Figure 4.27: Forward output at forced V_{BE}

Forward output, forced I_B

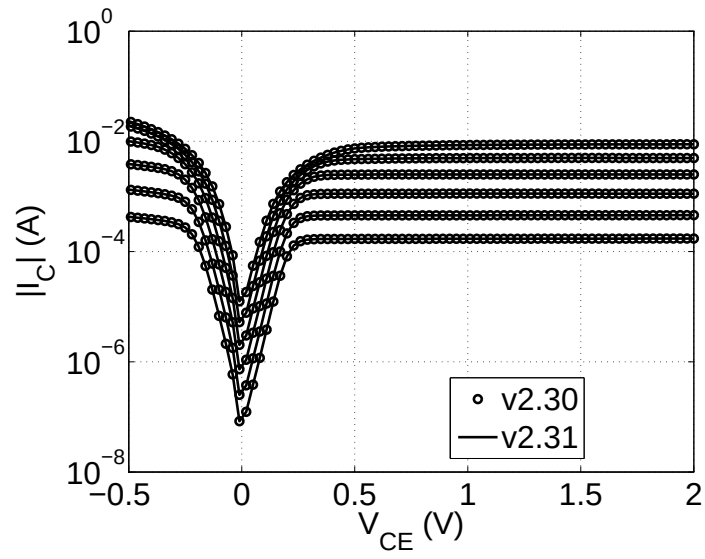


Figure 4.28: Forward output at forced I_B

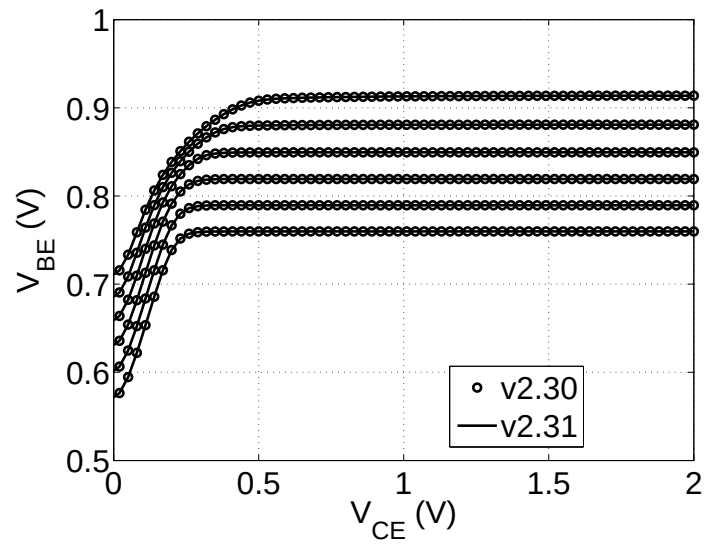


Figure 4.29: Forward output at forced I_B

Small signal results

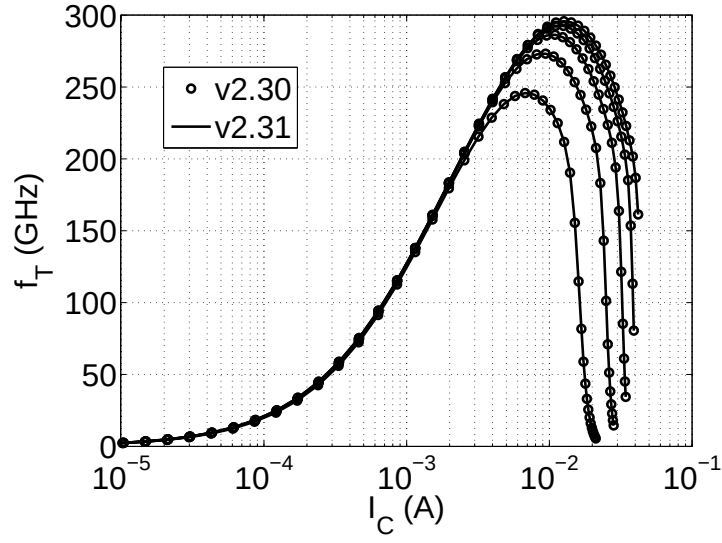


Figure 4.30: Transit frequency versus collector current at room temperature for $V_{BC} = -0.9...0.3V$

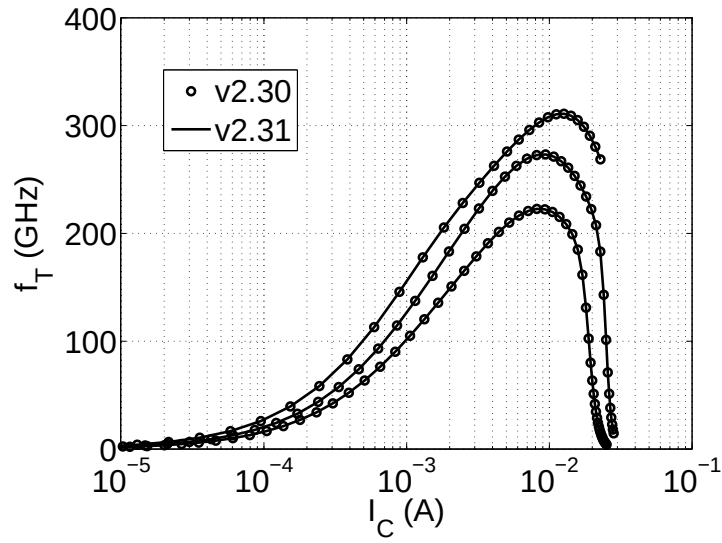


Figure 4.31: Transit frequency versus collector current at $V_{BC} = 0.0V$ and $T = [200, 300, 400]K$

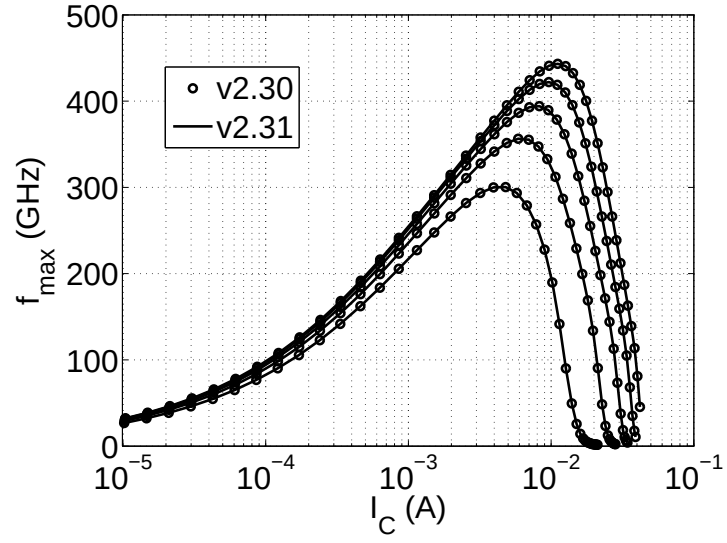


Figure 4.32: Maximum oscillation frequency versus collector current at room temperature for $V_{BC} = -0.9...0.3V$

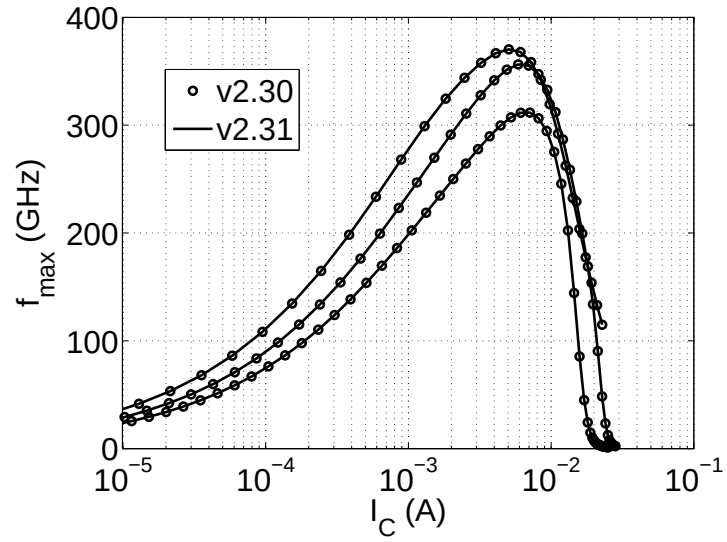


Figure 4.33: Maximum oscillation frequency versus collector current at $V_{BC} = 0.0V$ and $T = [200, 300, 400]K$

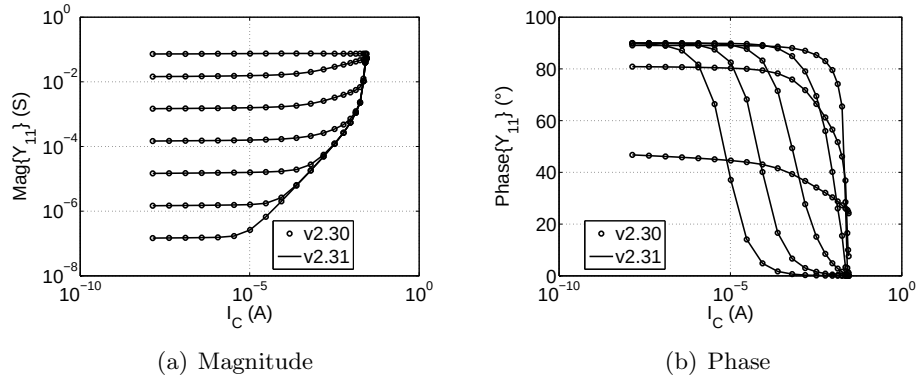


Figure 4.34: Magnitude and phase of Y_{11} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

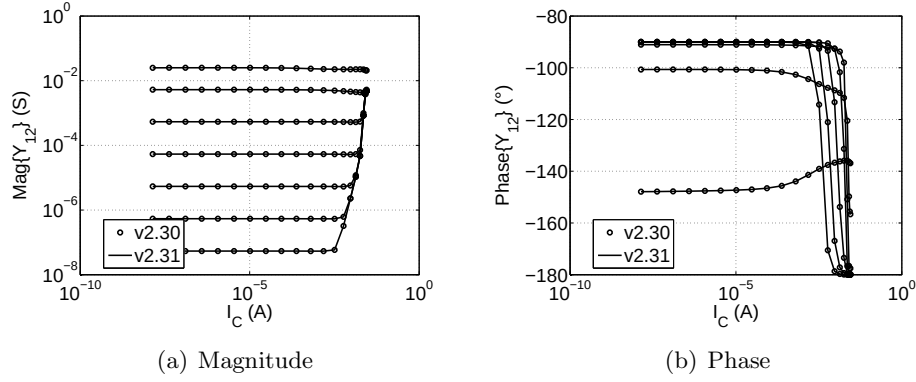


Figure 4.35: Magnitude and phase of Y_{12} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

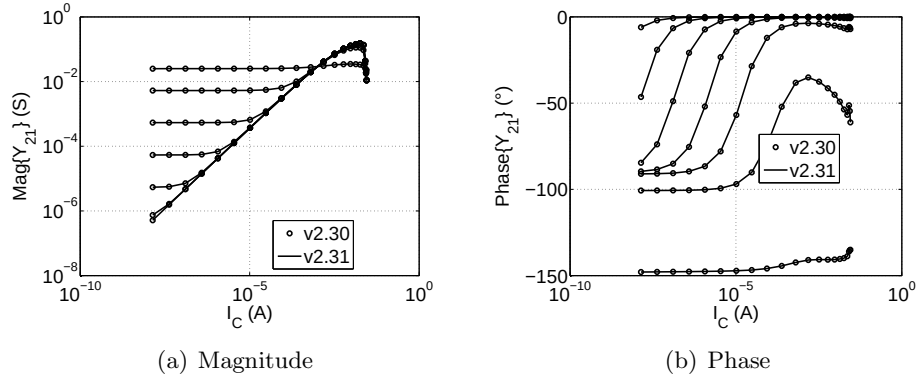


Figure 4.36: Magnitude and phase of Y_{21} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

4 Complete transistor

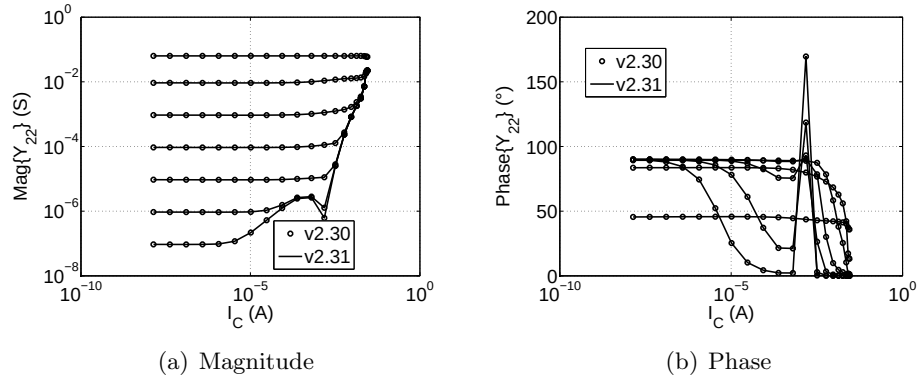


Figure 4.37: Magnitude and phase of Y_{22} versus collector current for $f=1\text{ MHz}\dots 1\text{ THz}$ at $V_{BC} = 0.0V$ and room temperature

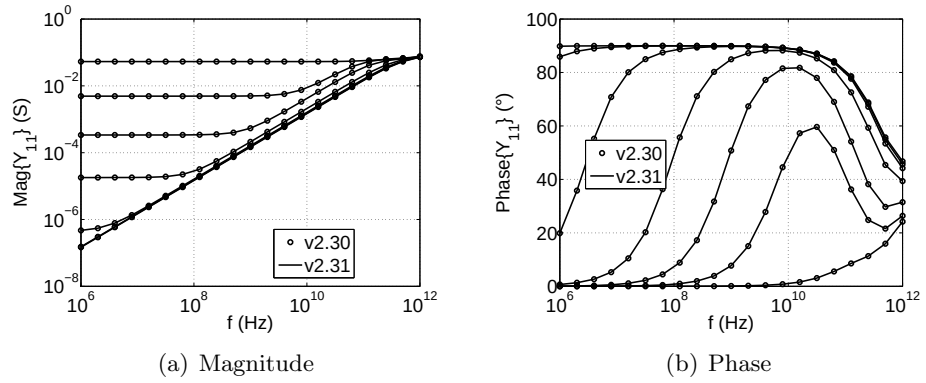


Figure 4.38: Magnitude and phase of Y_{11} versus frequency for $V_{BE} = 0.5\dots 1.1V$ at $V_{BC} = 0.0V$ and room temperature

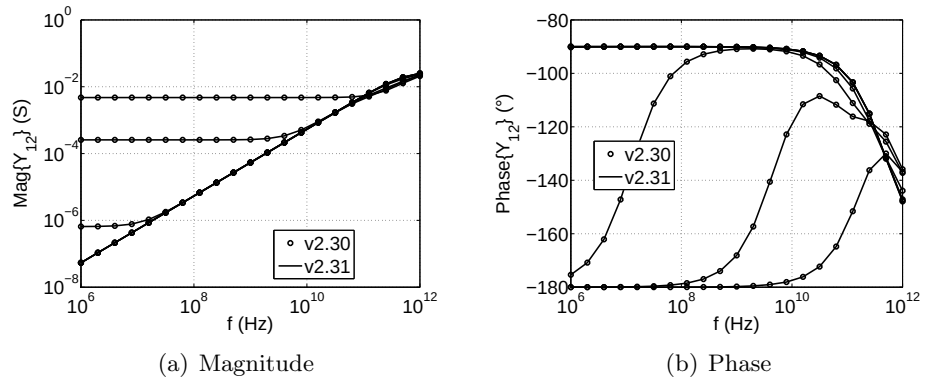


Figure 4.39: Magnitude and phase of Y_{12} versus frequency for $V_{BE} = 0.5\dots 1.1V$ at $V_{BC} = 0.0V$ and room temperature

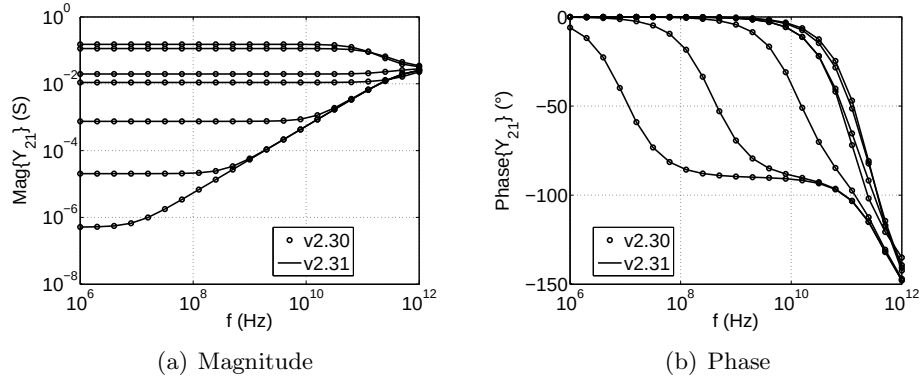


Figure 4.40: Magnitude and phase of Y_{21} versus frequency for $V_{BE} = 0.5 \dots 1.1V$ at $V_{BC} = 0.0V$ and room temperature

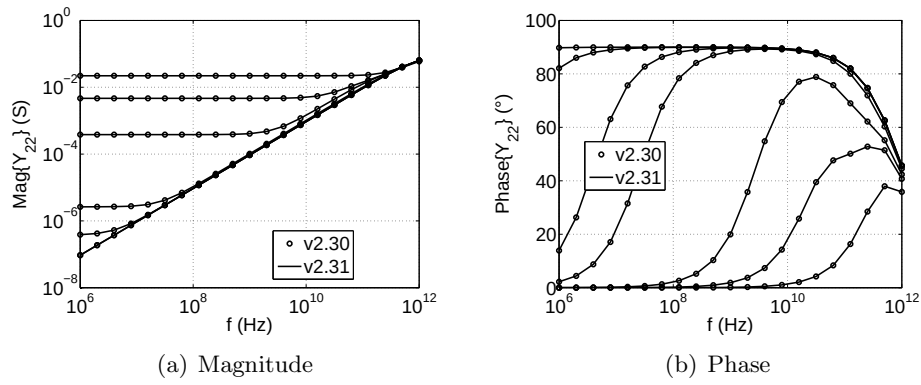


Figure 4.41: Magnitude and phase of Y_{22} versus frequency for $V_{BE} = 0.5 \dots 1.1V$ at $V_{BC} = 0.0V$ and room temperature

Noise modeling

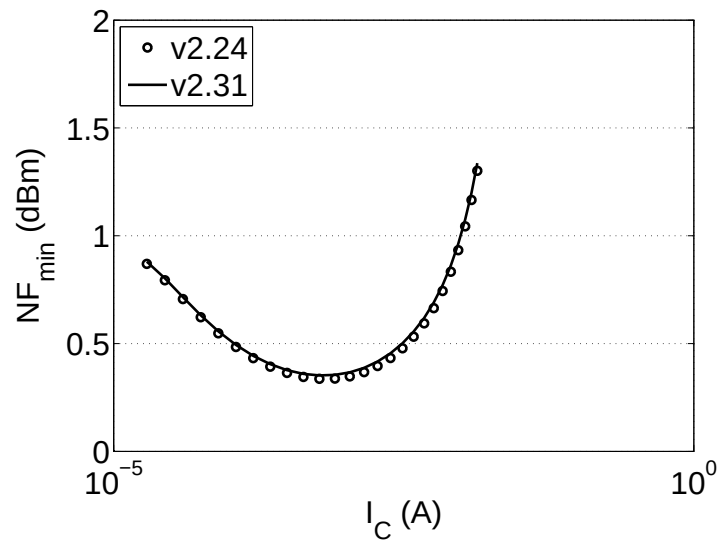


Figure 4.42: Minimum noise figure versus collector current at room temperature

5 Complete transistor including self-heating

5.1 Model cards

5.1.1 Version 2.31, compatible to 2.24

```
c10=2.0175e-032 qp0=2.155e-016 ich=0 hfe=1.8331
hfc=0.05 hjei=0.034883 hjci=0.0026778 ibeis=1.41e-020
mbei=1.012 ireis=1.3583e-015 mrei=2.263 ibeps=1.41e-020
mbep=1.012 ireps=1.3583e-015 mrep=2.263 mcf=1 tbhrec=1e-012
ibcis=5.825e-020 mbci=1.066 ibcx=5.825e-020 mbcx=1.066
ibets=1e-014 abet=40 tunode=1 favl=240.3 qavl=1.1756e-013
alfav=-0.009966 alqav=-0.0009569 rbi0=25 rbx=11 fgeo=0.6557
fdqr0=13 fcrbi=0 fqi=1 re=2.503 rcx=10.55 itss=0 msf=1
iscs=0 msc=1 tsf=0 rsu=0 csu=0 cjei0=4.6632e-015
vdei=0.87043 zei=0.20065 ajei=2.1953 cjep0=4.6632e-015
vdep=0.87043 zep=0.20065 ajep=2.1953 cjci0=3.7096e-015
vdci=0.73351 zci=0.36198 vptci=3.2461 cjcx0=0 vdcx=0.7 zcx=0.4
vptcx=100 fbcpar=0 fbepar=1 cjs0=7.06e-015 vds=0.6 zs=0.17
vpts=100 t0=2.2784e-013 dt0h=1.0591e-013 tbvl=1.5456e-014
tef0=4.4727e-013 gtfe=1.4744 thcs=1e-011 ahc=0.06 fthc=0.5
rci0=19.44 vlim=1.429 vces=0.001 vpt=18 tr=0
cbepar=3.81e-015 cbcpar=4.86e-015 alqf=0.16667 alit=0.33333
flnqs=0 kf=0 af=2 cfbe=-1 latb=0 latl=0 vgb=0.9
alt0=0.0025354 kt0=1e-005 zetaci=0.5621 alvs=0.00217
alces=-0.00584 zetarbi=0 zetarbx=0 zetarcx=0.191 zetare=0.2042
zetacx=-3.2 vge=1.17 vgc=1.17 vgs=1.17 flvg=-0.00010238
f2vg=0.00043215 zetact=5.3125 zetabet=1.3855 alb=0 flsh=1
rth=2539 cth=1e-011 flcomp=2.2 tnom=27 dt=0 zetarth=0
type=1 flcono=0
```

5.1.2 Version 2.31, compatible to 2.30

```
c10=2.0175e-032 qp0=2.155e-016 ich=0 hfe=1.8331
hfc=0.05 hjei=0.034883 hjci=0.0026778 ibeis=1.41e-020
mbei=1.012 ireis=1.3583e-015 mrei=2.263 ibeps=1.41e-020
mbep=1.012 ireps=1.3583e-015 mrep=2.263 mcf=1 tbhrec=1e-012
ibcis=5.825e-020 mbci=1.066 ibcx=5.825e-020 mbcx=1.066
ibets=1e-014 abet=40 tunode=1 favl=240.3 qavl=1.1756e-013
```

5 Complete transistor including self-heating

```
alfav=-0.009966 alqav=-0.0009569 rbi0=25 rbx=11 fgeo=0.6557
fdqr0=13 fcrbi=0 fqi=1 re=2.503 rcx=10.55 itss=0 msf=1
iscs=0 msc=1 tsf=0 rsu=0 csu=0 cjei0=4.6632e-015
vdei=0.87043 ze1=0.20065 aje1=2.1953 cjep0=4.6632e-015
vdep=0.87043 zep=0.20065 ajep=2.1953 cjci0=3.7096e-015
vdc1=0.73351 zci=0.36198 vptci=3.2461 cjc1=0 vdcx=0.7 zcx=0.4
vptcx=100 fbcpar=0 fbepar=1 cjs0=7.06e-015 vds=0.6 zs=0.17
vpts=100 t0=2.2784e-013 dt0h=1.0591e-013 tbvl=1.5456e-014
tef0=4.4727e-013 gtfe=1.4744 thcs=1e-011 ahc=0.06 fthc=0.5
rci0=19.44 vlim=1.429 vces=0.001 vpt=18 tr=0
cbepar=3.81e-015 cbcpar=4.86e-015 alqf=0.16667 alit=0.33333
flnqs=0 kf=0 af=2 cfbe=-1 latb=0 latl=0 vgb=0.9
alt0=0.0025354 kt0=1e-005 zetaci=0.5621 alvs=0.00217
alces=-0.00584 zetarbi=0 zetarbx=0 zetarcx=0.191 zeta1=0.2042
zetacx=-3.2 vge=1.17 vgc=1.17 vgs=1.17 flvg=-0.00010238
f2vg=0.00043215 zetact=5.3125 zetabet=1.3855 alb=0 flsh=1
rth=2539 cth=1e-011 flcomp=2.3 tnom=27 dt=0 zetarth=0.84
type=1 flcono=0 hf0=0.24679 ahjei=5.912 rhjei=2
vcbar=0.04 icbar=0.003 acbar=1.5 delck=1.8 dvgbe=-0.1103
zetahjei=-0.78133 zeta1vgbe=0.7 alrth=0
```

5.2 Simulation results

5.2.1 Comparison between version 2.31 and 2.24

Forward gummel

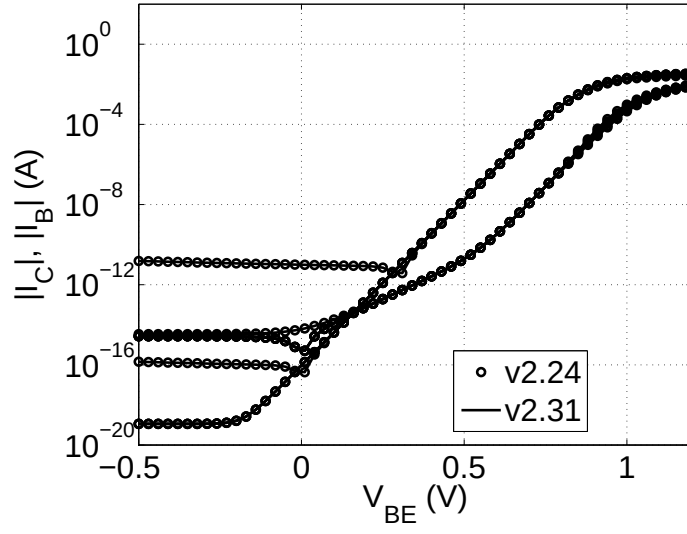


Figure 5.1: Forward gummel at room temperature for $V_{BC} = -0.9 \dots 0.3V$

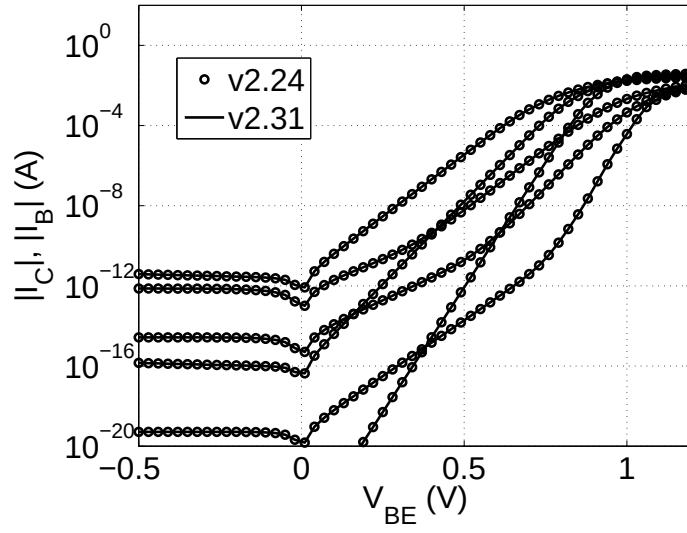


Figure 5.2: Forward gummel at $V_{BC} = 0.0V$ and $T = [200, 300, 400]K$

Reverse gummel

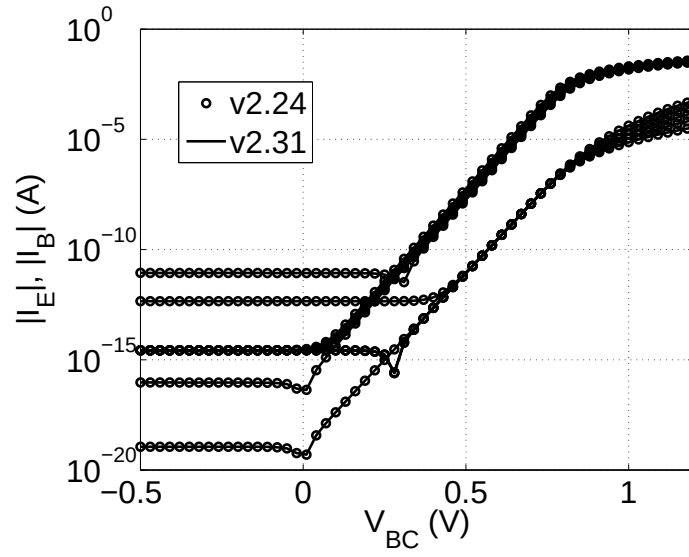


Figure 5.3: Reverse gummel at room temperature for $V_{BE} = -0.9...0.3V$

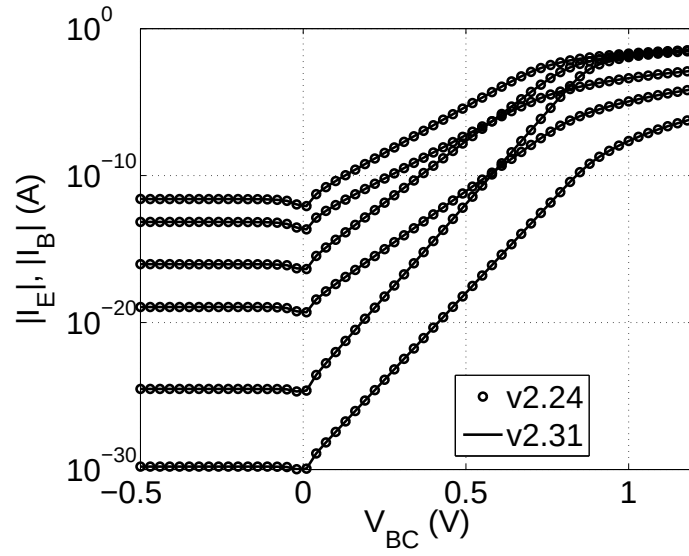
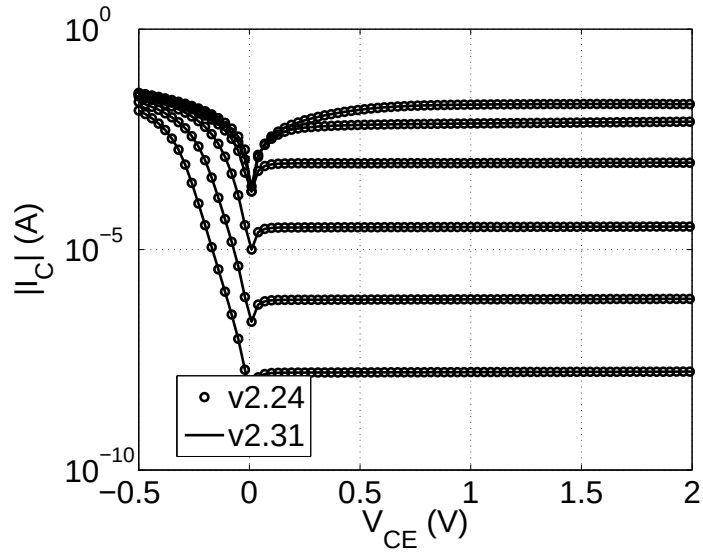
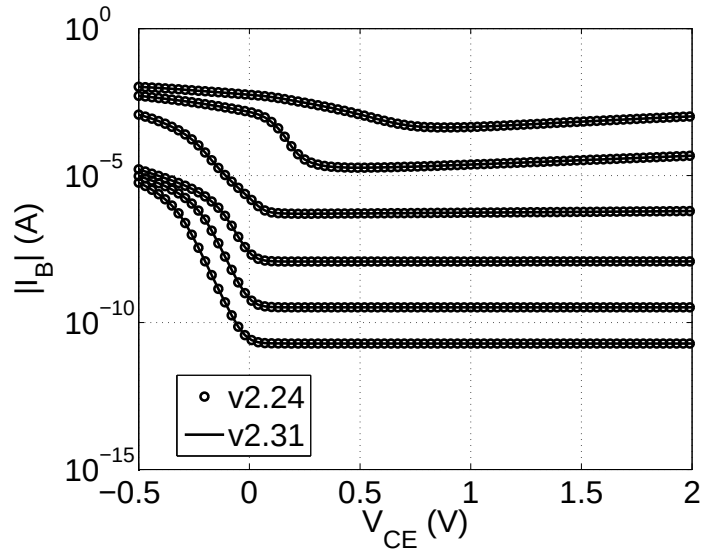


Figure 5.4: Reverse gummel at $V_{BE} = 0.0V$ and $T = [200, 300, 400]K$

Forward output, forced V_{BE} Figure 5.5: Forward output at forced V_{BE} Figure 5.6: Forward output at forced V_{BE}

Forward output, forced I_B

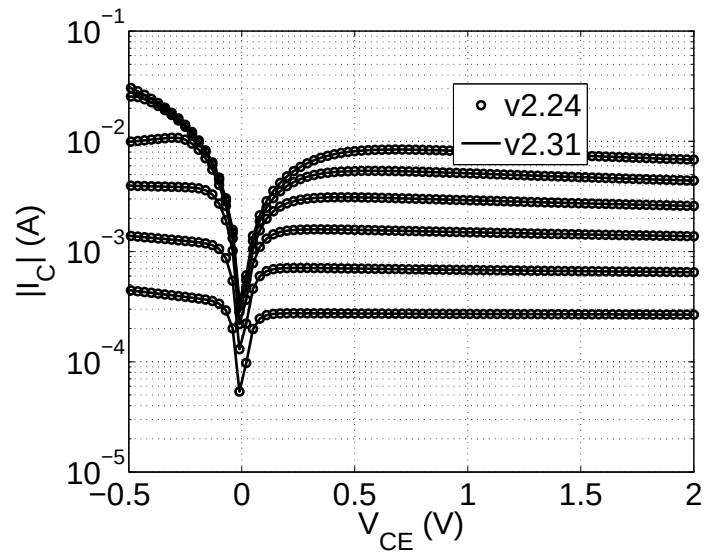


Figure 5.7: Forward output at forced I_B

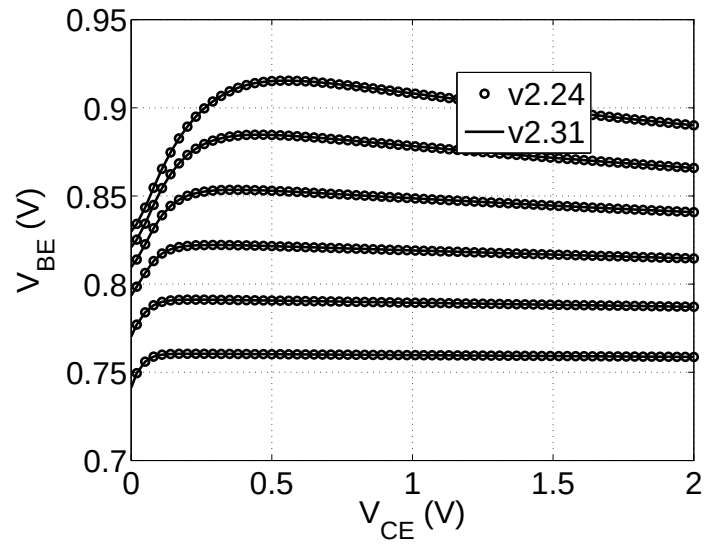


Figure 5.8: Forward output at forced I_B

Small signal results

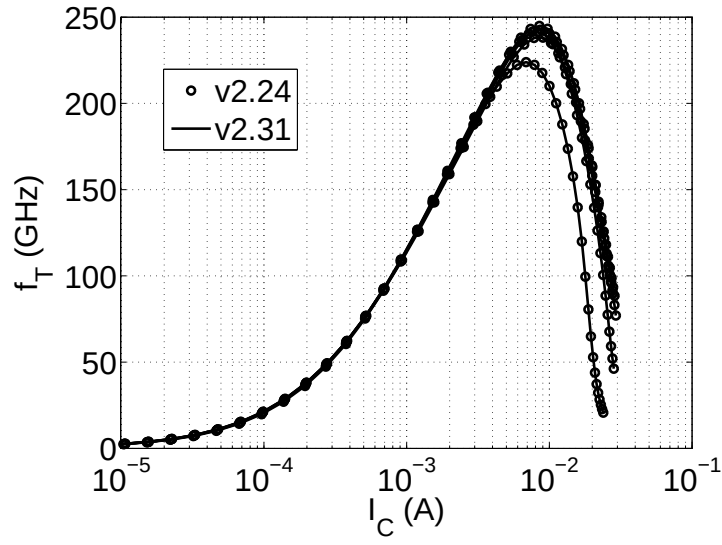


Figure 5.9: Transit frequency versus collector current at room temperature for $V_{BC} = -0.9 \dots 0.3V$

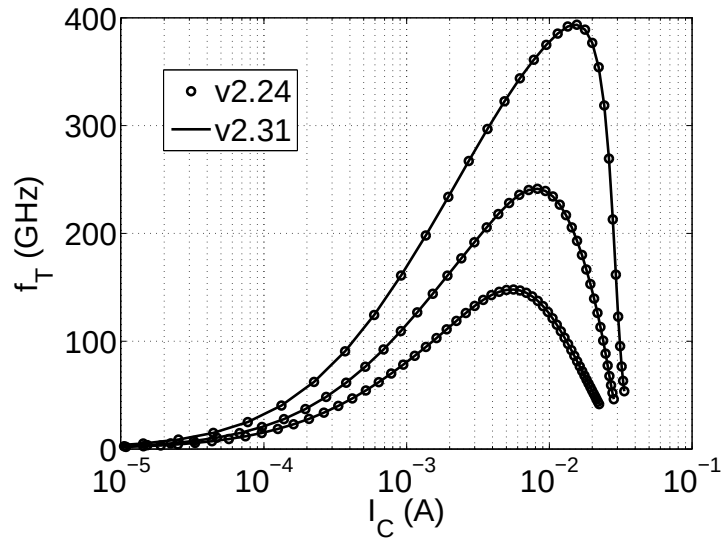


Figure 5.10: Transit frequency versus collector current at $V_{BC} = 0.0V$ and $T = [200, 300, 400]K$

5 Complete transistor including self-heating

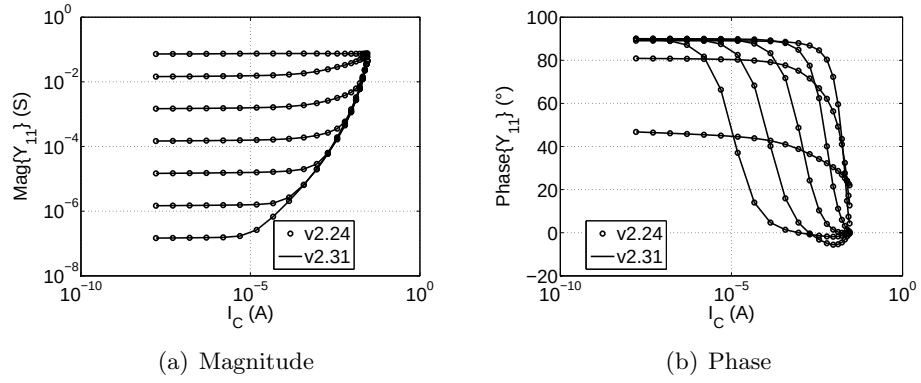


Figure 5.11: Magnitude and phase of Y_{11} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

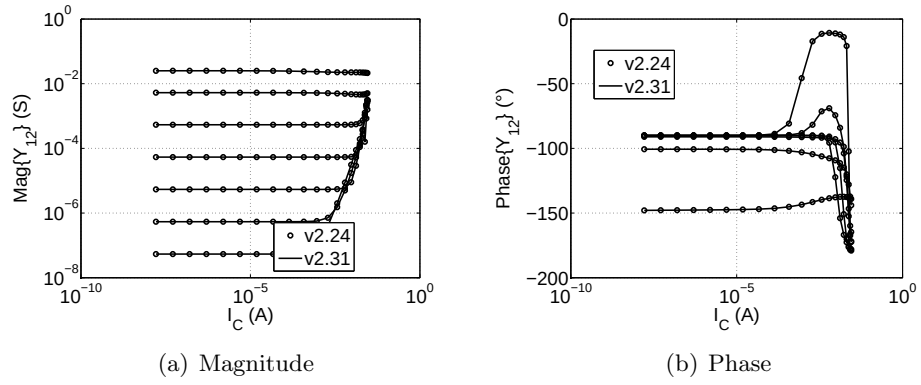


Figure 5.12: Magnitude and phase of Y_{12} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

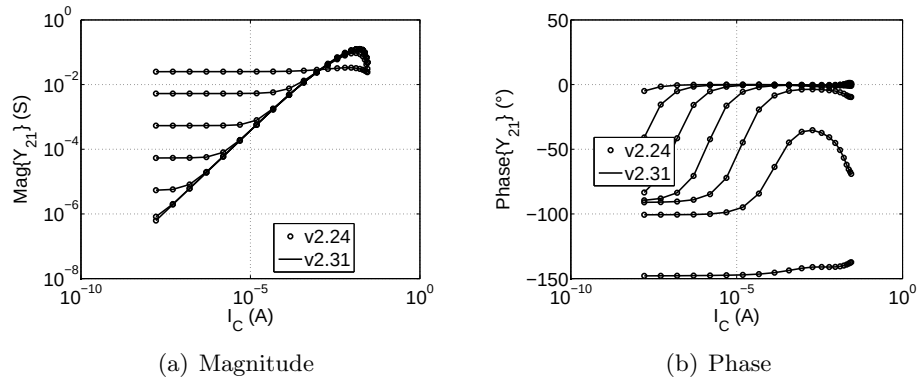


Figure 5.13: Magnitude and phase of Y_{21} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

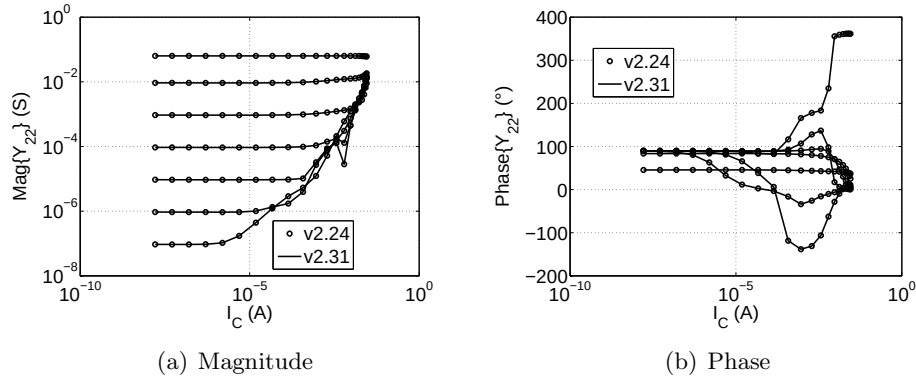


Figure 5.14: Magnitude and phase of Y_{22} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

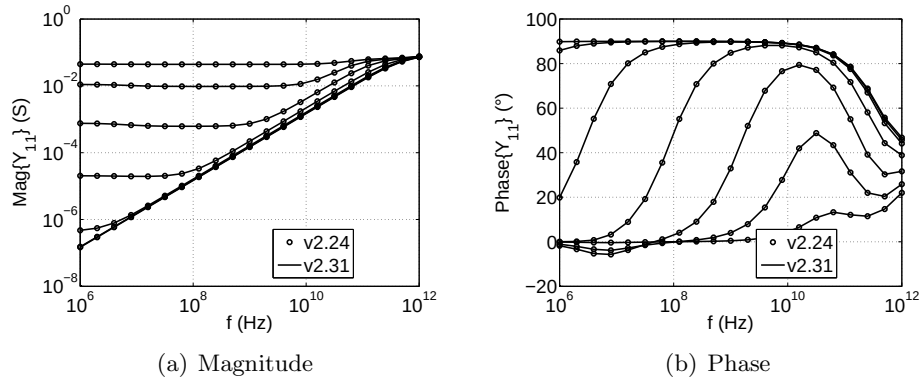


Figure 5.15: Magnitude and phase of Y_{11} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

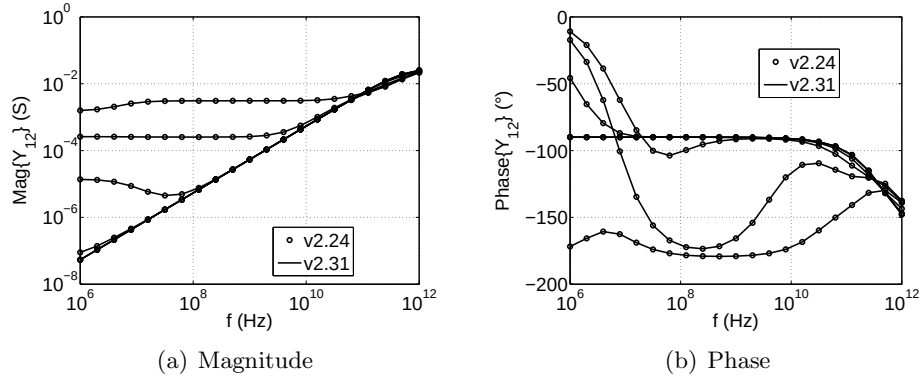


Figure 5.16: Magnitude and phase of Y_{12} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

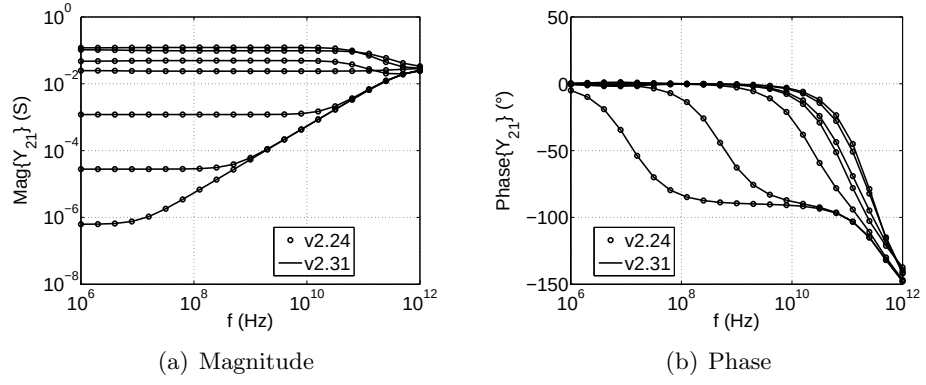


Figure 5.17: Magnitude and phase of Y_{21} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

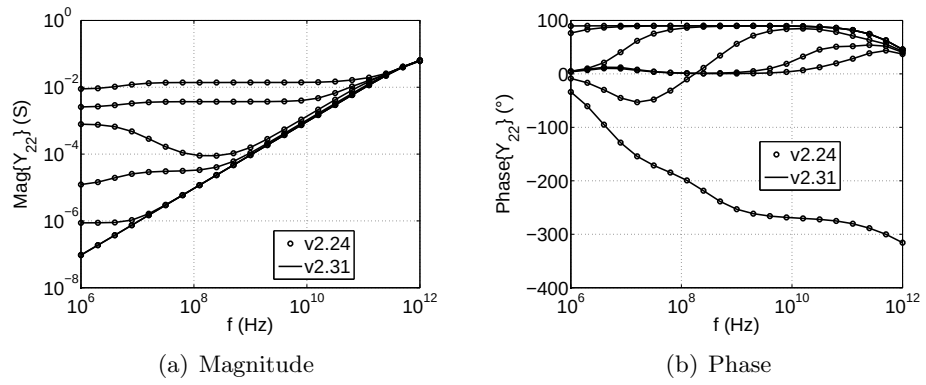
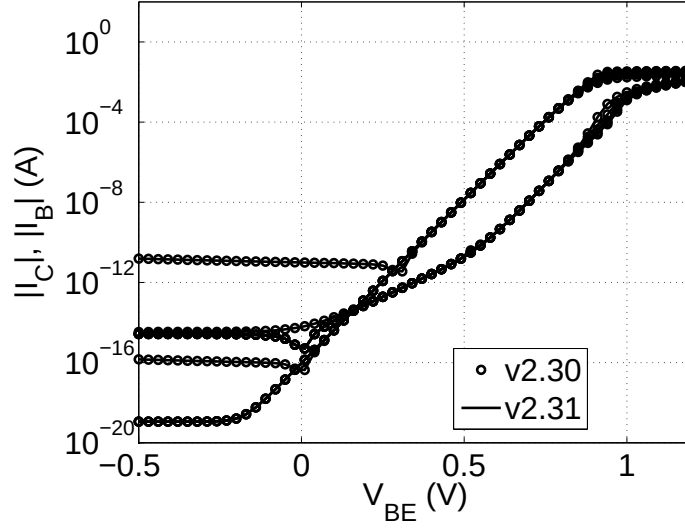
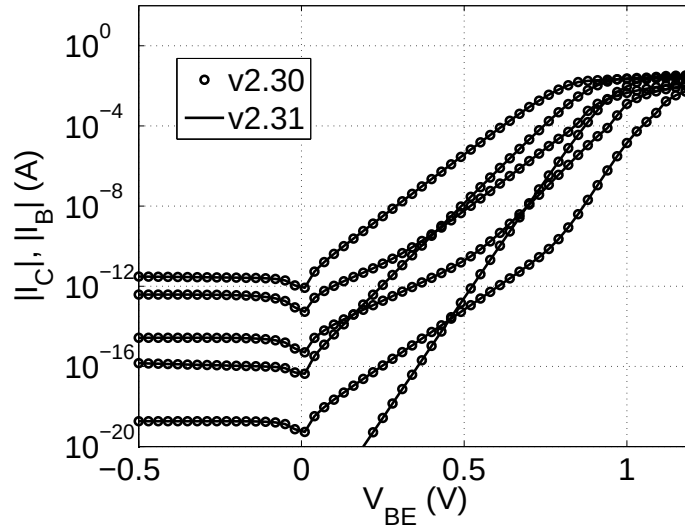


Figure 5.18: Magnitude and phase of Y_{22} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

5.2.2 Comparison between version 2.31 and 2.30

Forward gummel

Figure 5.19: Forward gummel at room temperature for $V_{BC} = -0.9...0.3V$ Figure 5.20: Forward gummel at $V_{BC} = 0.0V$ and $T = [200, 300, 400]K$

Reverse gummel

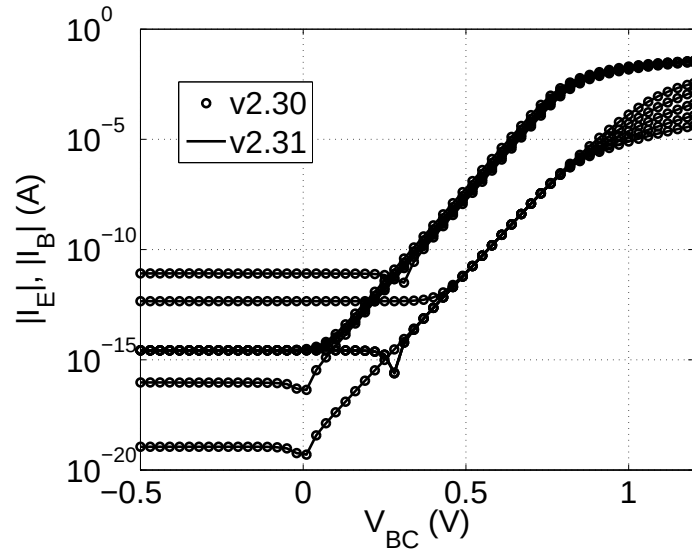


Figure 5.21: Reverse gummel at room temperature for $V_{BE} = -0.9...0.3V$

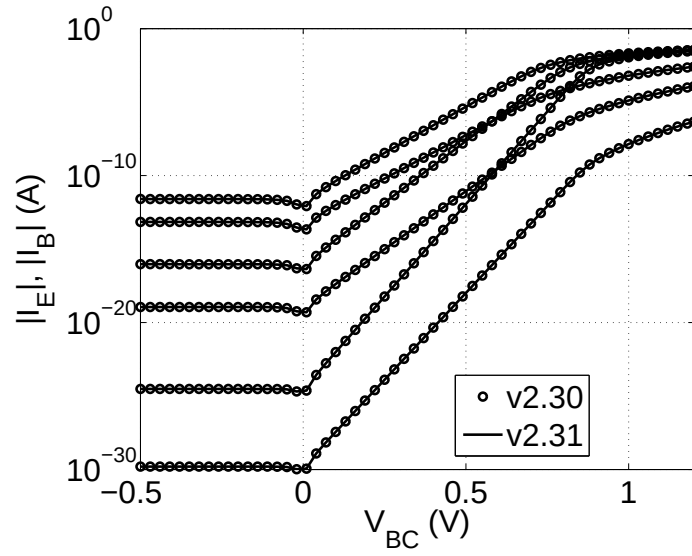
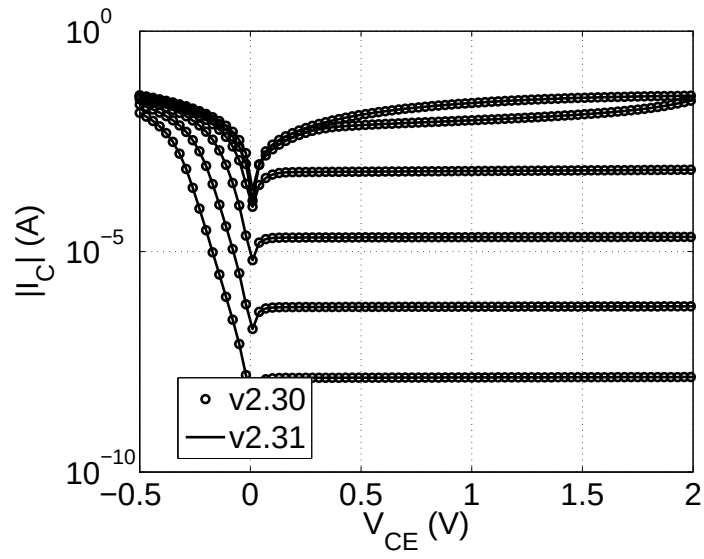
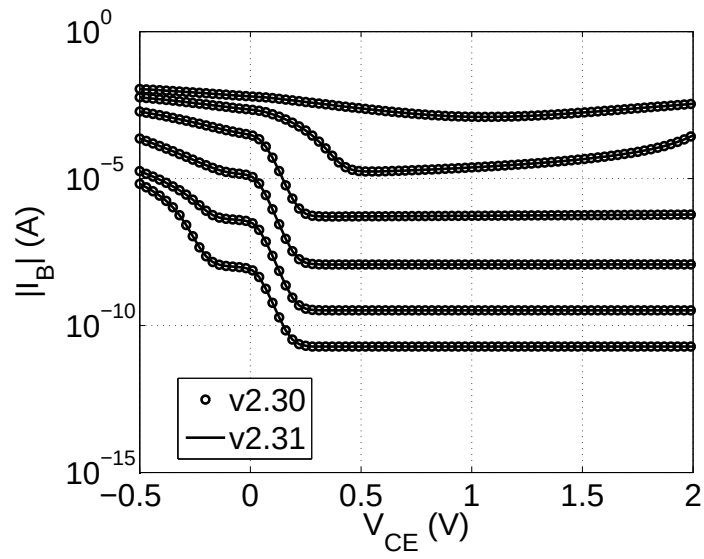


Figure 5.22: Reverse gummel at $V_{BE} = 0.0V$ and $T = [200, 300, 400]K$

Forward output, forced V_{BE} Figure 5.23: Forward output at forced V_{BE} Figure 5.24: Forward output at forced V_{BE}

Forward output, forced I_B

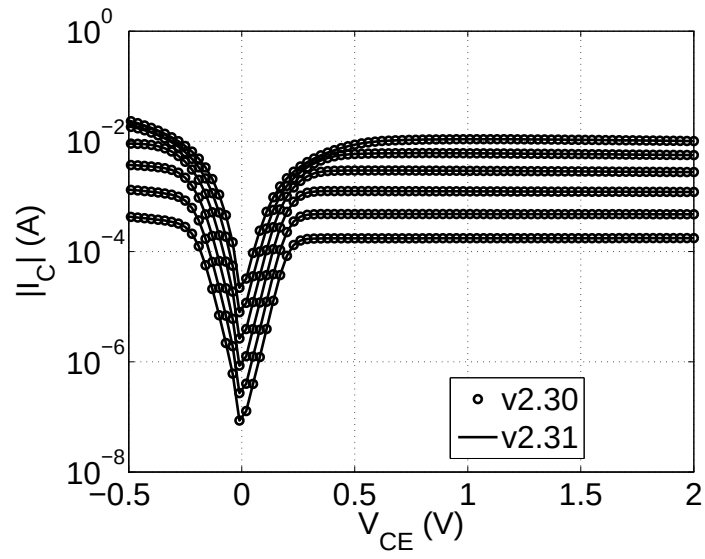


Figure 5.25: Forward output at forced I_B

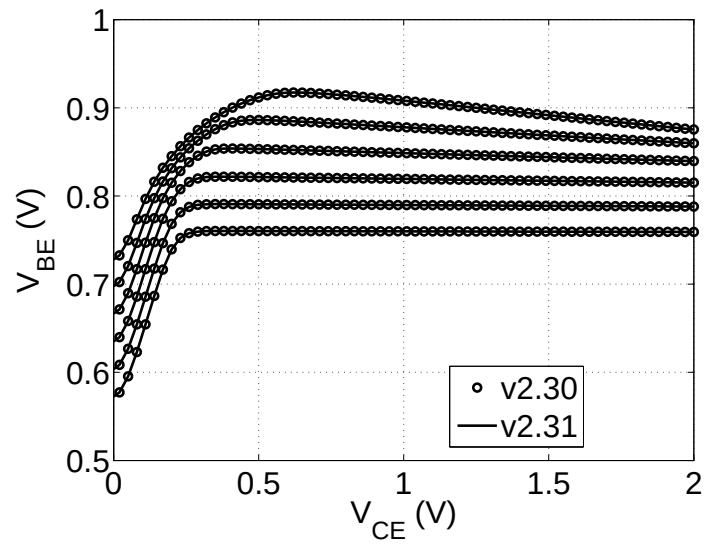


Figure 5.26: Forward output at forced I_B

Small signal results

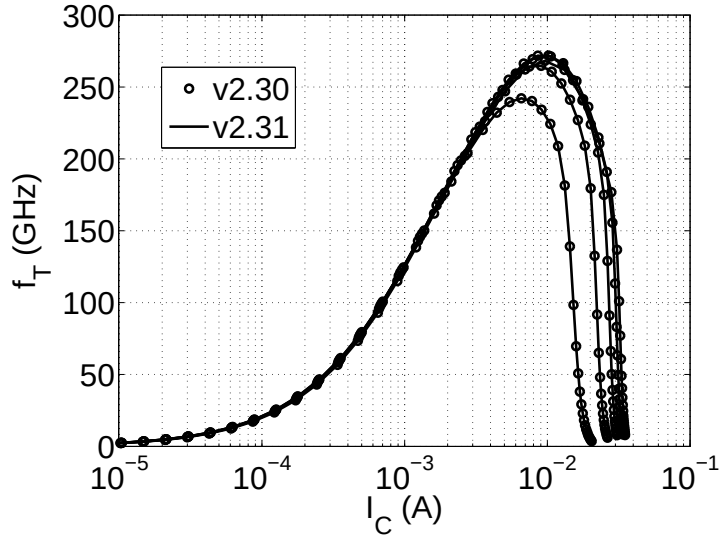


Figure 5.27: Transit frequency versus collector current at room temperature for $V_{BC} = -0.9 \dots 0.3V$

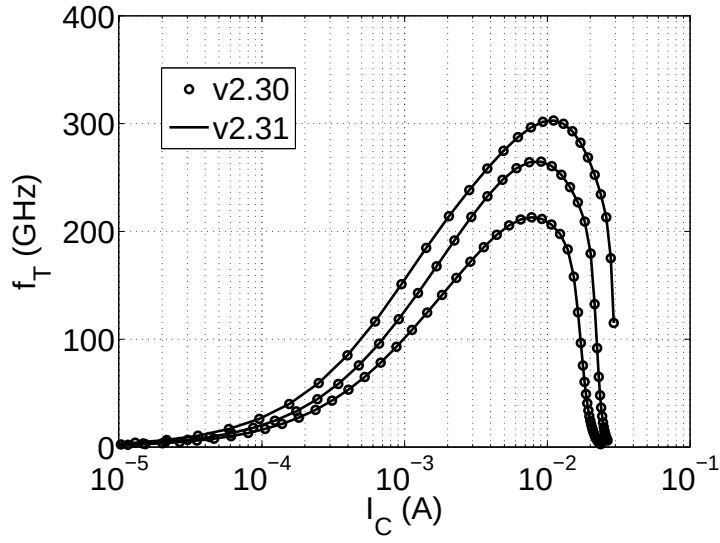


Figure 5.28: Transit frequency versus collector current at $V_{BC} = 0.0V$ and $T = [200, 300, 400]K$

5 Complete transistor including self-heating

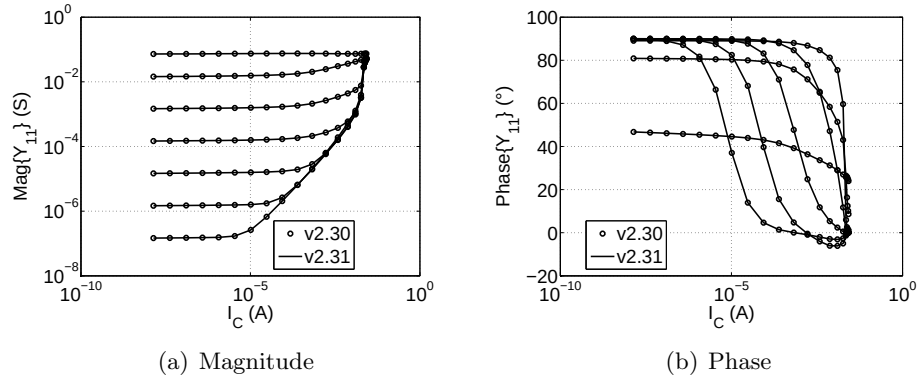


Figure 5.29: Magnitude and phase of Y_{11} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

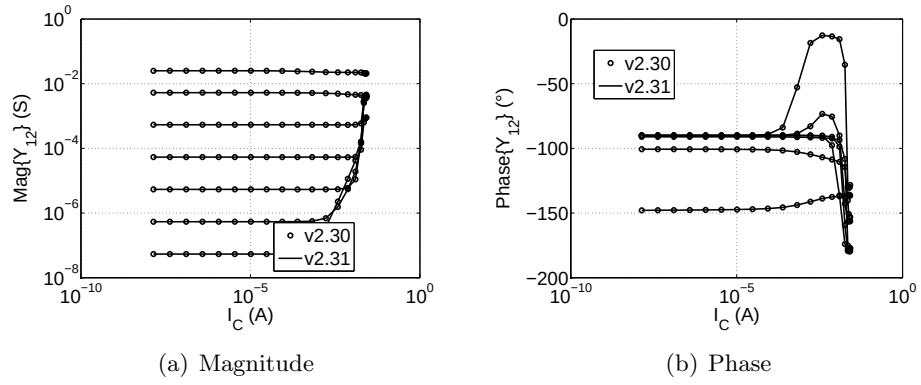


Figure 5.30: Magnitude and phase of Y_{12} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

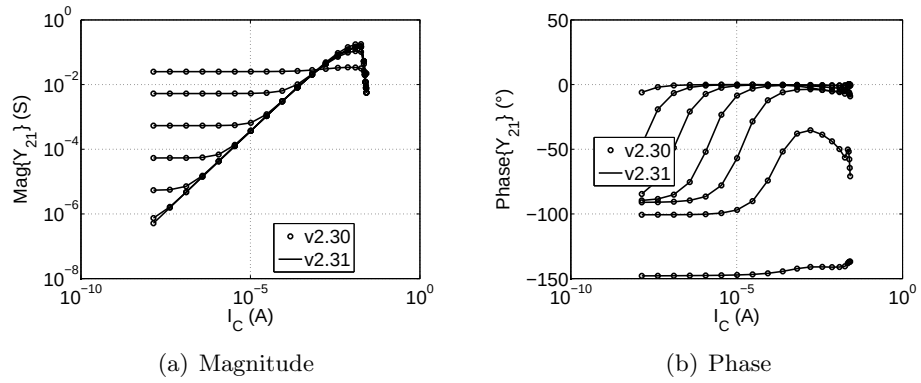


Figure 5.31: Magnitude and phase of Y_{21} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

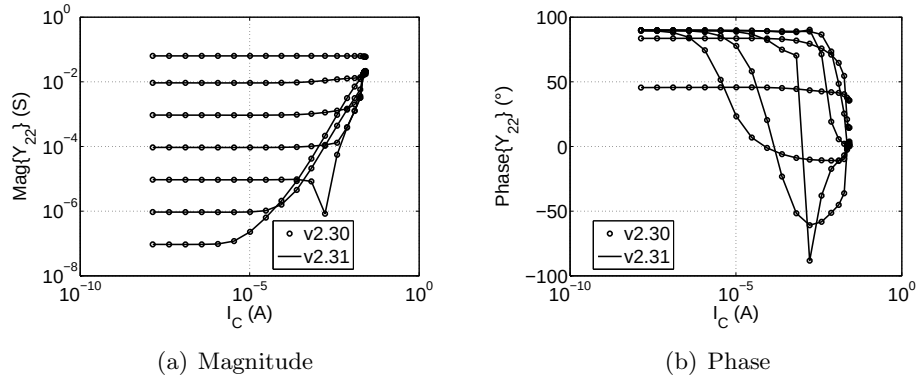


Figure 5.32: Magnitude and phase of Y_{22} versus collector current for $f=1\text{ MHz}\dots 1\text{ THz}$ at $V_{BC} = 0.0V$ and room temperature

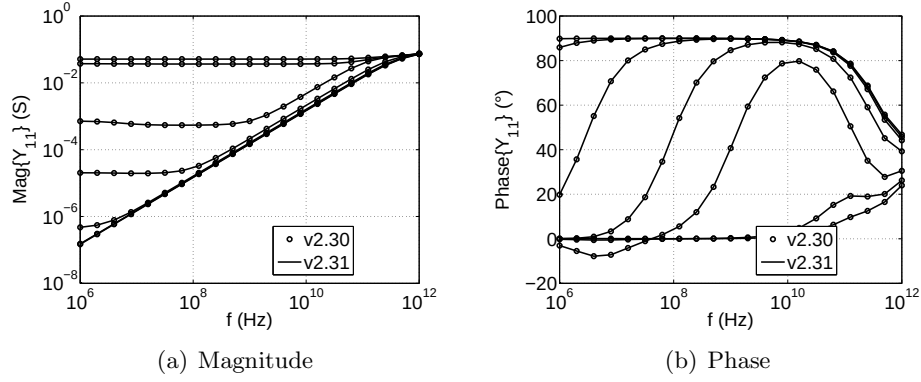


Figure 5.33: Magnitude and phase of Y_{11} versus frequency for $V_{BE} = 0.5\dots 1.1V$ at $V_{BC} = 0.0V$ and room temperature

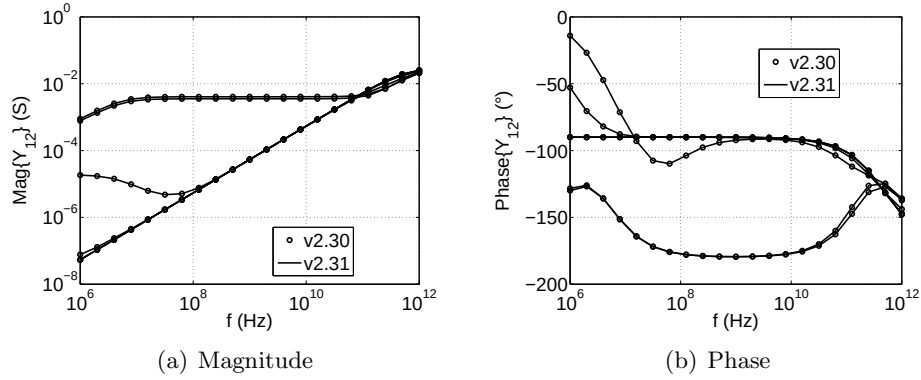


Figure 5.34: Magnitude and phase of Y_{12} versus frequency for $V_{BE} = 0.5\dots 1.1V$ at $V_{BC} = 0.0V$ and room temperature

5 Complete transistor including self-heating

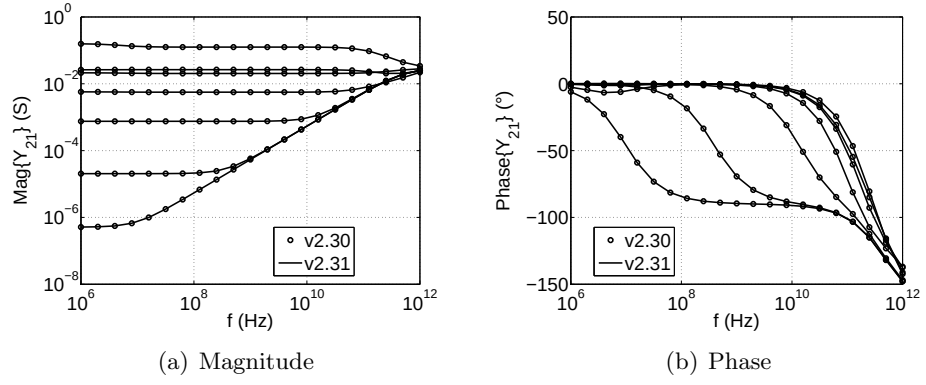


Figure 5.35: Magnitude and phase of Y_{21} versus frequency for $V_{BE} = 0.5 \dots 1.1V$ at $V_{BC} = 0.0V$ and room temperature

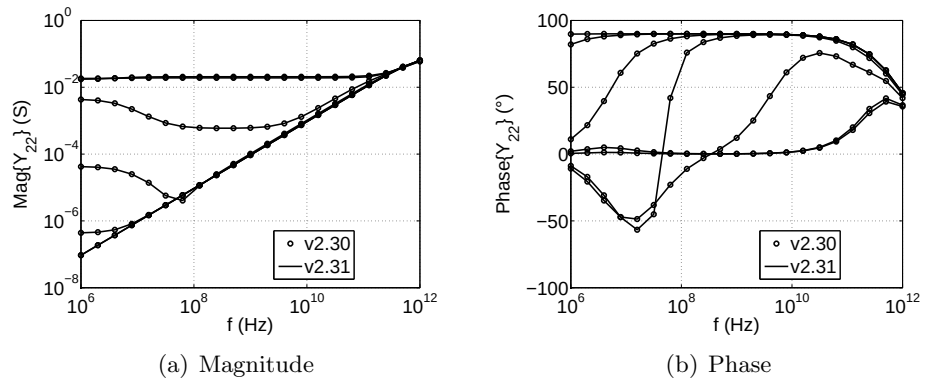


Figure 5.36: Magnitude and phase of Y_{22} versus frequency for $V_{BE} = 0.5 \dots 1.1V$ at $V_{BC} = 0.0V$ and room temperature

6 Complete transistor including substrate-transistor

6.1 Model cards

6.1.1 Version 2.31, compatible to 2.24

```
c10=2.0175e-032 qp0=2.155e-016 ich=0 hfe=1.8331
hfc=0.05 hjei=0.034883 hjci=0.0026778 ibeis=1.41e-020
mbei=1.012 ireis=1.3583e-015 mrei=2.263 ibeps=1.41e-020
mbep=1.012 ireps=1.3583e-015 mrep=2.263 mcf=1 tbhrec=1e-012
ibcis=5.825e-020 mbci=1.066 ibcxs=5.825e-020 mbcx=1.066
ibets=1e-014 abet=40 tunode=1 favl=240.3 qavl=1.1756e-013
alfav=-0.009966 alqav=-0.0009569 rbi0=25 rbx=11 fgeo=0.6557
fdqr0=13 fcrbi=0 fqi=1 re=2.503 rcx=10.55 itss=1e-014
msf=1 iscs=1e-015 msc=1 tsf=0 rsu=0 csu=0
cjei0=4.6632e-015 vdei=0.87043 zei=0.20065 ajei=2.1953
cjep0=4.6632e-015 vdep=0.87043 zep=0.20065 ajep=2.1953
cji0=3.7096e-015 vdc=0.73351 zci=0.36198 vptci=3.2461 cjc0=0
vdcx=0.7 zcx=0.4 vptcx=100 fbcpar=0 fbepar=1
cjs0=7.06e-015 vds=0.6 zs=0.17 vpts=100 t0=2.2784e-013
dt0h=1.0591e-013 tbvl=1.5456e-014 tef0=4.4727e-013 gtfe=1.4744
thcs=1e-011 ahc=0.06 fthc=0.5 rci0=19.44 vlim=1.429
vces=0.001 vpt=18 tr=0 cbepar=3.81e-015 cbcpar=4.86e-015
alqf=0.16667 alit=0.33333 flnqs=0 kf=0 af=2 cfbe=-1 latb=0
latl=0 vgb=0.9 alt0=0.0025354 kt0=1e-005 zetaci=0.5621
alvs=0.00217 alces=-0.00584 zetarbi=0 zetarbx=0 zetarcx=0.191
zetare=0.2042 zetacx=-3.2 vge=1.17 vgc=1.17 vgs=0.807
flvg=-0.00010238 f2vg=0.00043215 zetact=5.3125 zetabet=1.3855
alb=0 flsh=0 rth=0 cth=0 flcomp=2.2 tnom=27 dt=0
zetarth=0 type=1 flcono=0
```

6.1.2 Version 2.31, compatible to 2.30

```
c10=2.0175e-032 qp0=2.155e-016 ich=0 hfe=1.8331
hfc=0.05 hjei=0.034883 hjci=0.0026778 ibeis=1.41e-020
mbei=1.012 ireis=1.3583e-015 mrei=2.263 ibeps=1.41e-020
mbep=1.012 ireps=1.3583e-015 mrep=2.263 mcf=1 tbhrec=1e-012
ibcis=5.825e-020 mbci=1.066 ibcxs=5.825e-020 mbcx=1.066
```

6 Complete transistor including substrate-transistor

```
ibets=1e-014 abet=40 tunode=1 favl=240.3 qavl=1.1756e-013
alfav=-0.009966 alqav=-0.0009569 rbi0=25 rbx=11 fgeo=0.6557
fdqr0=13 fcrbi=0 fqi=1 re=2.503 rcx=10.55 itss=1e-014
msf=1 iscs=1e-015 msc=1 tsf=0 rsu=0 csu=0
cjei0=4.6632e-015 vdei=0.87043 zei=0.20065 ajei=2.1953
cjep0=4.6632e-015 vdep=0.87043 zep=0.20065 ajep=2.1953
cjci0=3.7096e-015 vdc=0.73351 zci=0.36198 vptci=3.2461 cjc0=0
vdcx=0.7 zcx=0.4 vptcx=100 fbcpar=0 fbepar=1
cjs0=7.06e-015 vds=0.6 zs=0.17 vpts=100 t0=2.2784e-013
dt0h=1.0591e-013 tbvl=1.5456e-014 tef0=4.4727e-013 gtfe=1.4744
thcs=1e-011 ahc=0.06 fthc=0.5 rci0=19.44 vlim=1.429
vces=0.001 vpt=18 tr=0 cbepar=3.81e-015 cbcpar=4.86e-015
alqf=0.16667 alit=0.33333 flnqs=0 kf=0 af=2 cfbe=-1 latb=0
latl=0 vgb=0.9 alt0=0.0025354 kt0=1e-005 zetaci=0.5621
alvs=0.00217 alces=-0.00584 zetarbi=0 zetarbx=0 zetarcx=0.191
zetare=0.2042 zetacx=-3.2 vge=1.17 vgc=1.17 vgs=0.807
flvg=-0.00010238 f2vg=0.00043215 zetact=5.3125 zetabet=1.3855
alb=0 flsh=0 rth=0 cth=0 flcomp=2.3 tnom=27 dt=0
zetarth=0 type=1 flcono=0 hf0=0.24679 ahjei=5.912 rhjei=2
vcbar=0.04 icbar=0.003 acbar=1.5 delck=1.8 dvgbe=-0.1103
zetahjei=-0.78133 zetavgbe=0.7 alrth=0
```

6.2 Simulation results

6.2.1 Comparison between version 2.31 and 2.24

Forward gummel

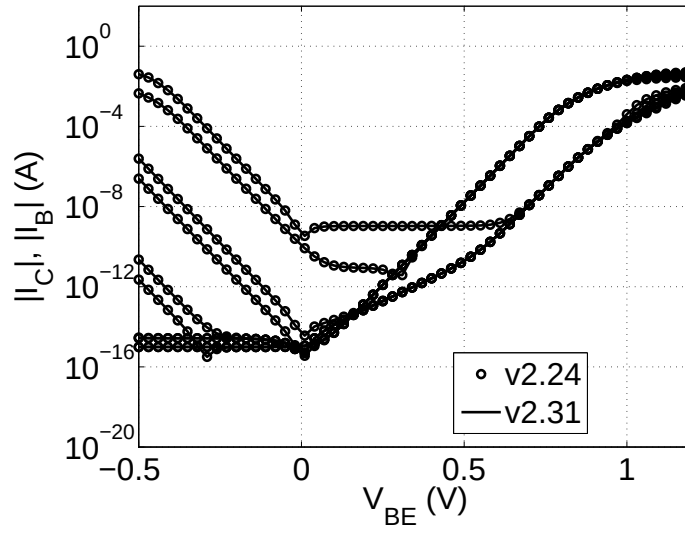


Figure 6.1: Forward gummel at room temperature for $V_{BC} = -0.9...0.3V$

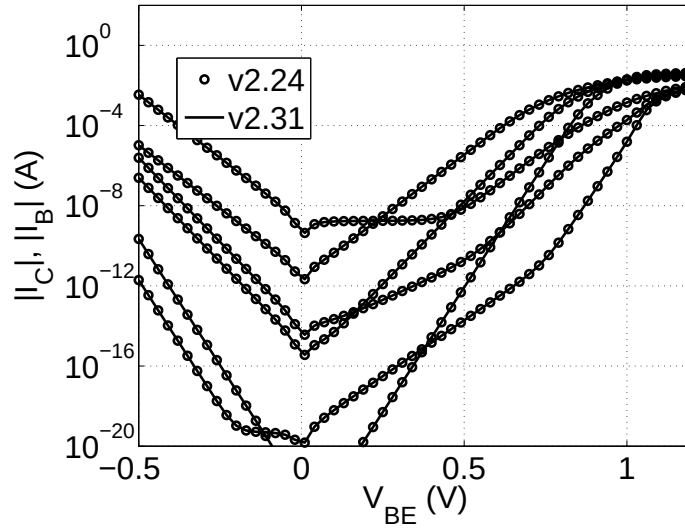


Figure 6.2: Forward gummel at $V_{BC} = 0.0V$ and $T = [200, 300, 400]K$

Reverse gummel

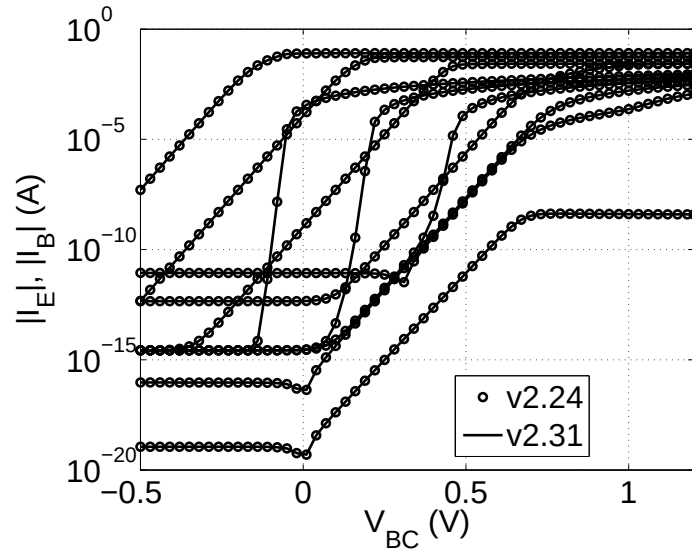


Figure 6.3: Reverse gummel at room temperature for $V_{BE} = -0.9...0.3V$

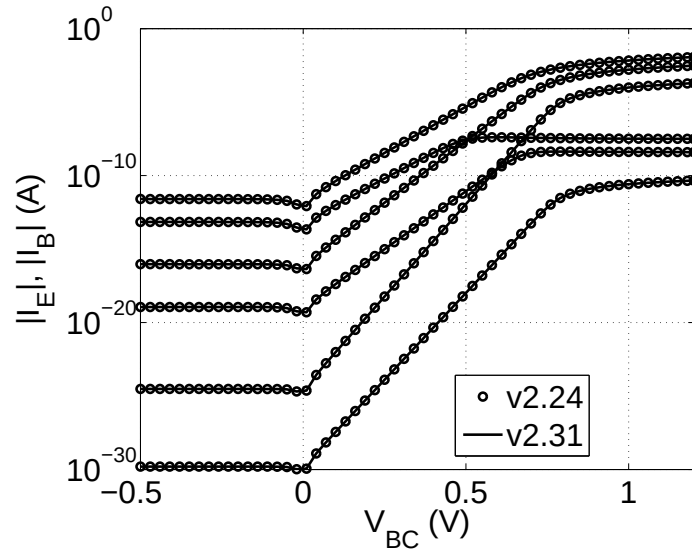
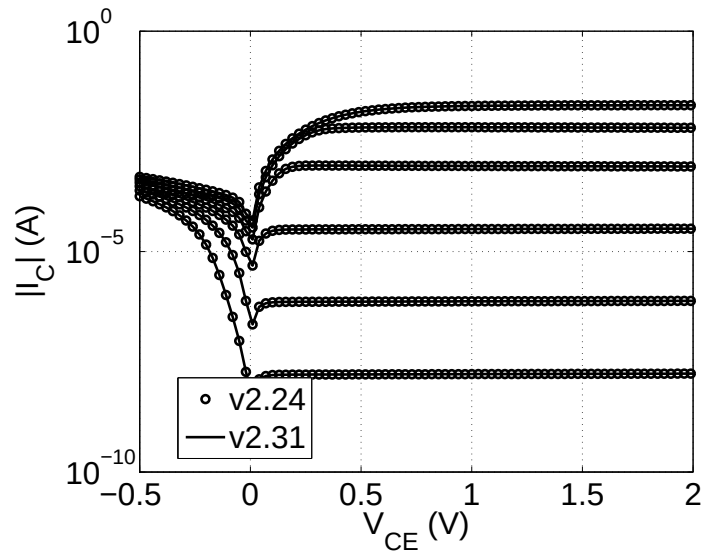
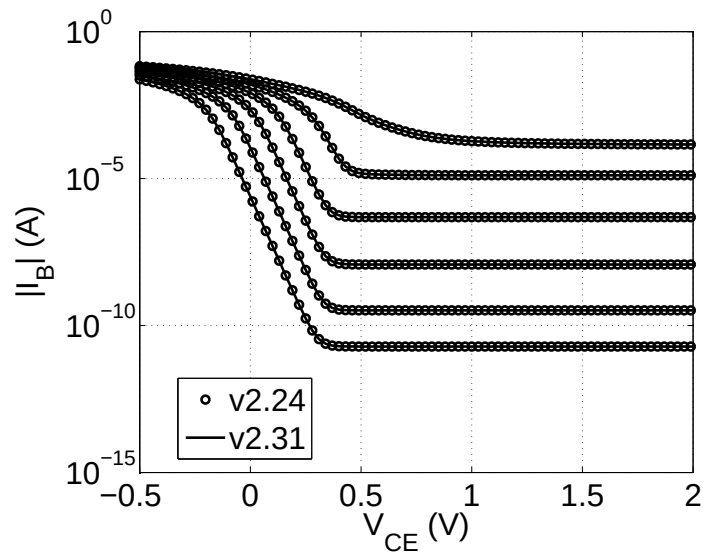


Figure 6.4: Reverse gummel at $V_{BE} = 0.0V$ and $T = [200, 300, 400]K$

Forward output, forced V_{BE} Figure 6.5: Forward output at forced V_{BE} Figure 6.6: Forward output at forced V_{BE}

Forward output, forced I_B

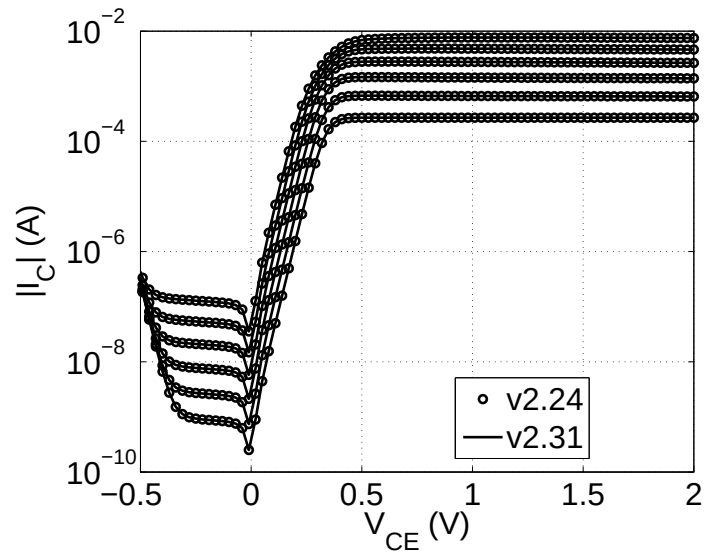


Figure 6.7: Forward output at forced I_B

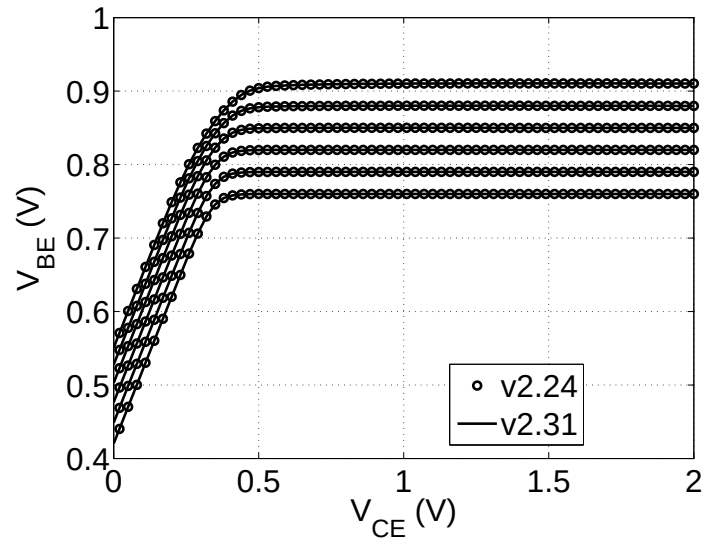


Figure 6.8: Forward output at forced I_B

Small signal results

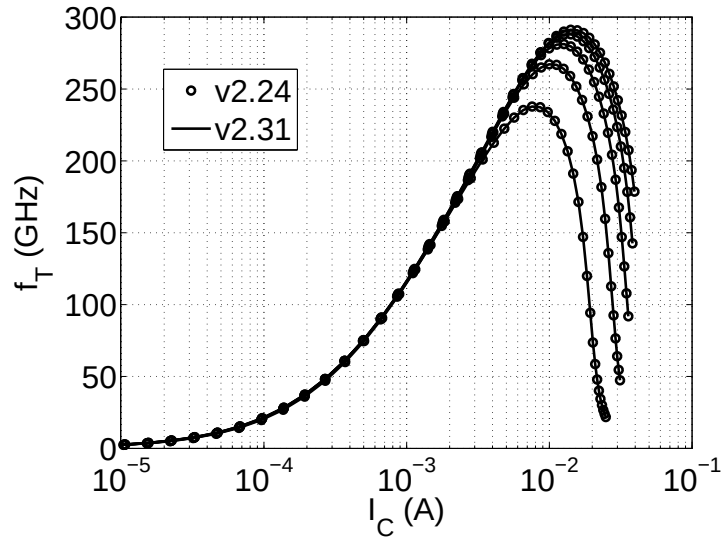


Figure 6.9: Transit frequency versus collector current at room temperature for $V_{BC} = -0.9 \dots 0.3V$

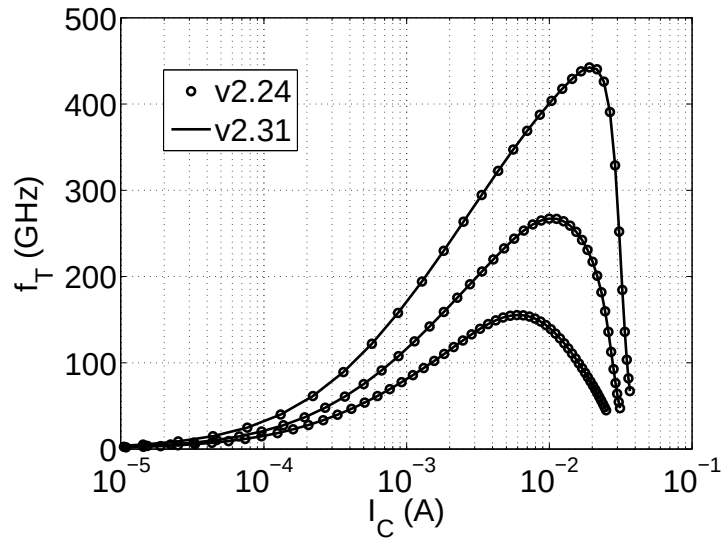


Figure 6.10: Transit frequency versus collector current at $V_{BC} = 0.0V$ and $T = [200, 300, 400]K$

6 Complete transistor including substrate-transistor

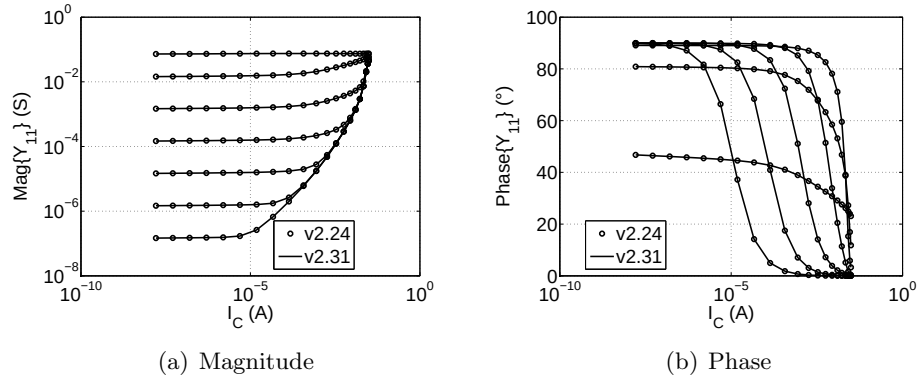


Figure 6.11: Magnitude and phase of Y_{11} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

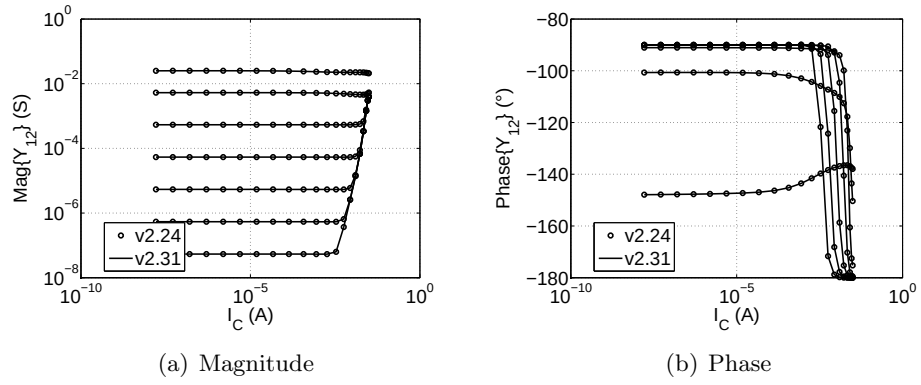


Figure 6.12: Magnitude and phase of Y_{12} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

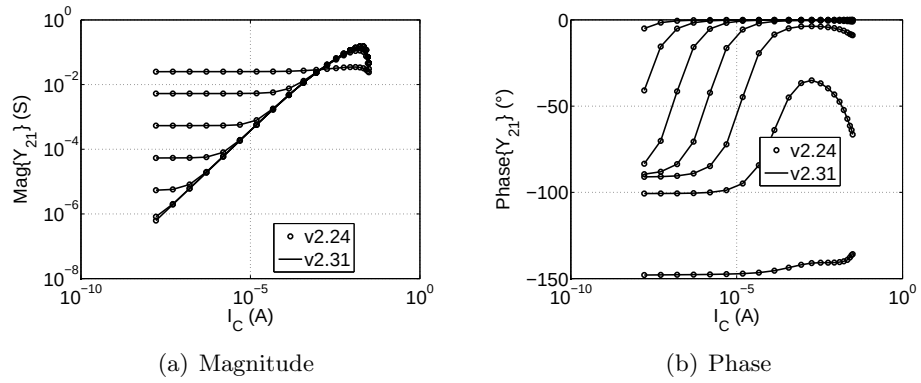


Figure 6.13: Magnitude and phase of Y_{21} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

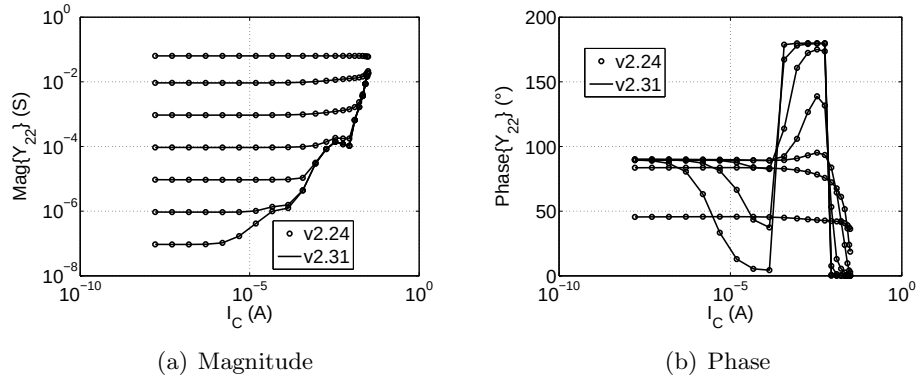


Figure 6.14: Magnitude and phase of Y_{22} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

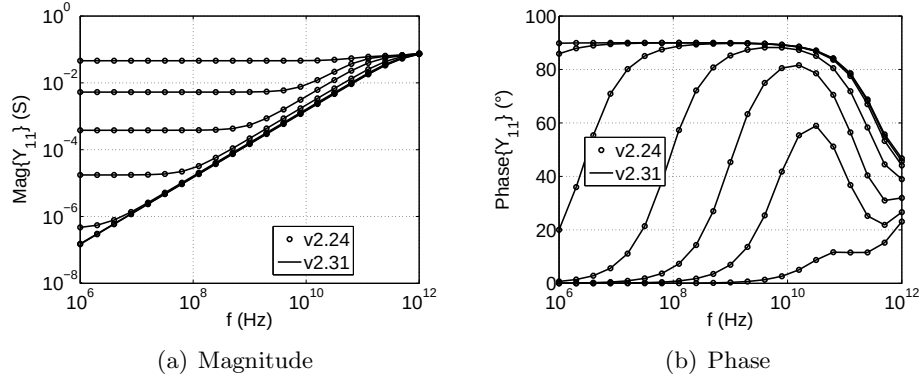


Figure 6.15: Magnitude and phase of Y_{11} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

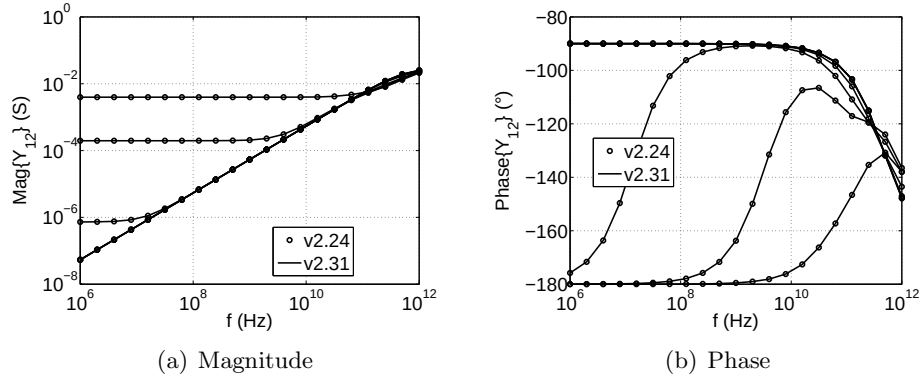


Figure 6.16: Magnitude and phase of Y_{12} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

6 Complete transistor including substrate-transistor

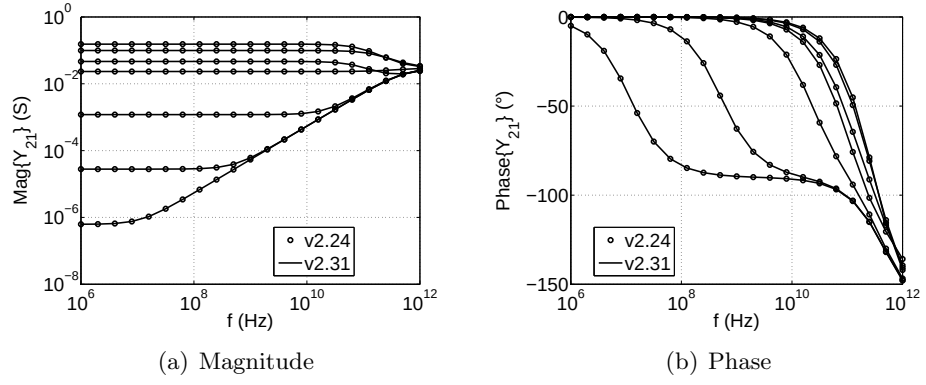


Figure 6.17: Magnitude and phase of Y_{21} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

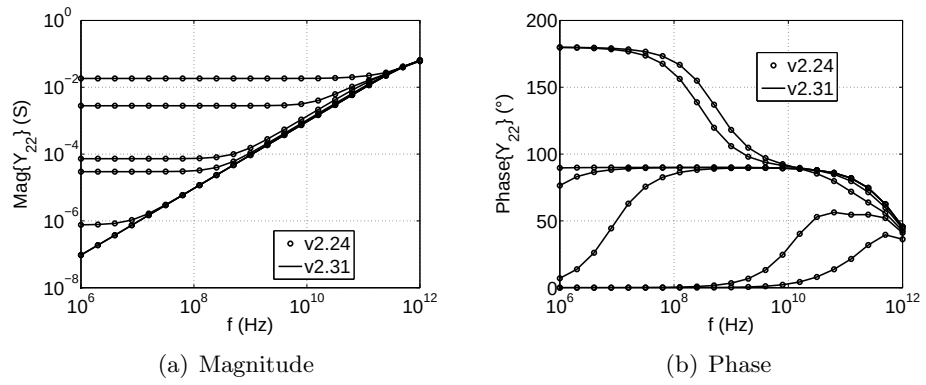


Figure 6.18: Magnitude and phase of Y_{22} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

6.2.2 Comparison between version 2.31 and 2.30

Forward gummel

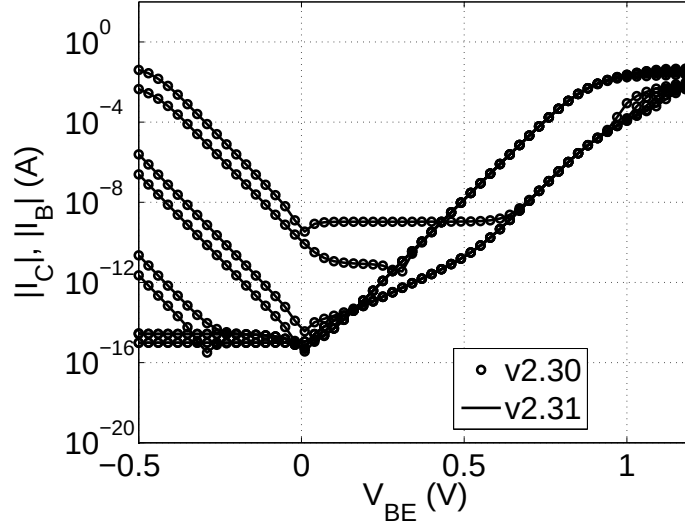


Figure 6.19: Forward gummel at room temperature for $V_{BC} = -0.9...0.3V$

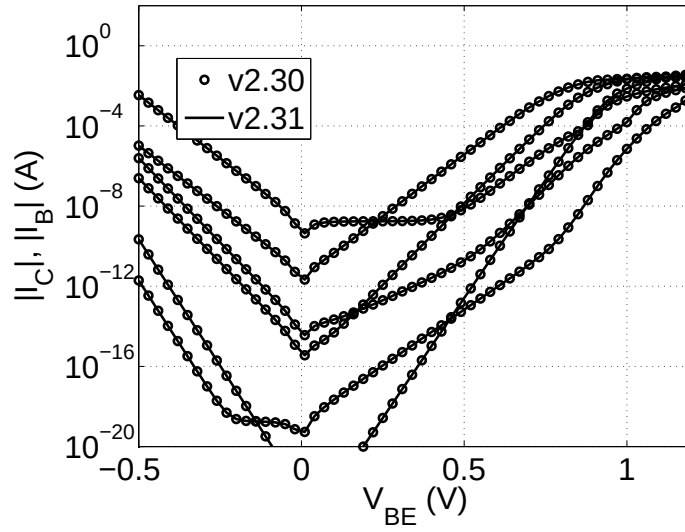


Figure 6.20: Forward gummel at $V_{BC} = 0.0V$ and $T = [200, 300, 400]K$

Reverse gummel

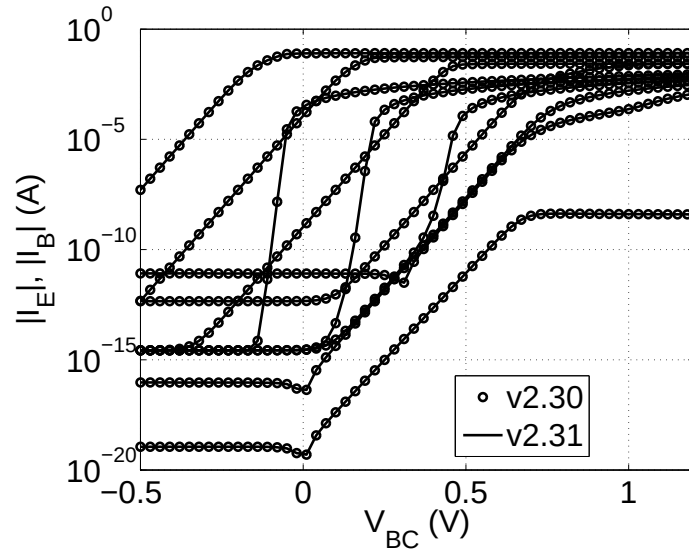


Figure 6.21: Reverse gummel at room temperature for $V_{BE} = -0.9...0.3V$

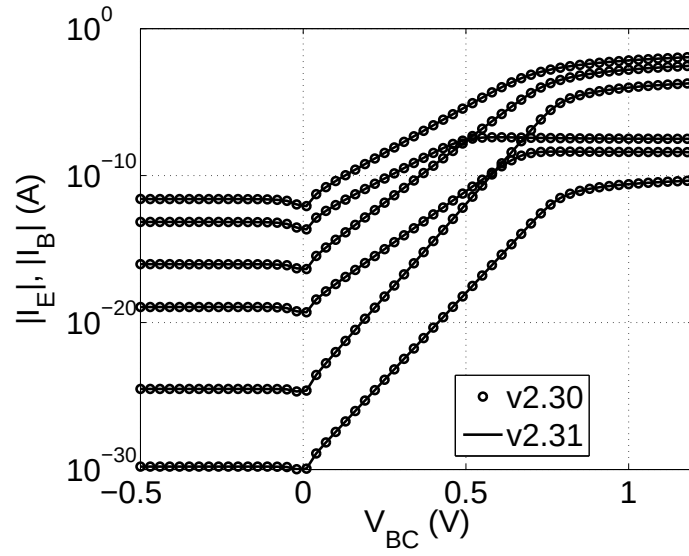
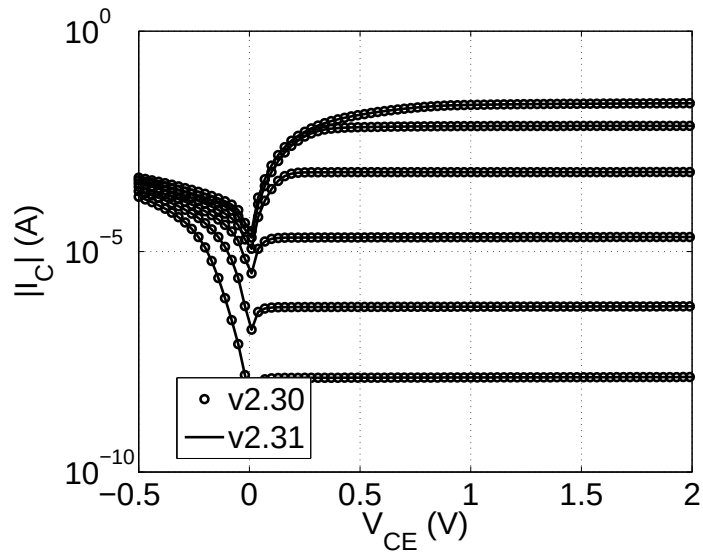
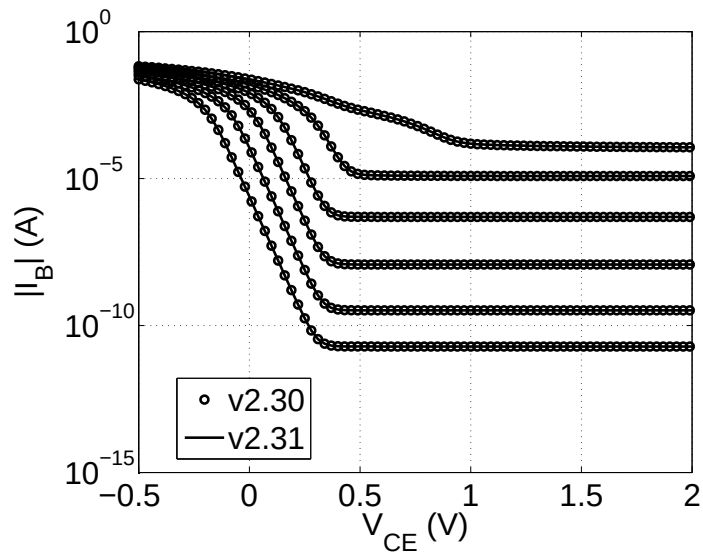


Figure 6.22: Reverse gummel at $V_{BE} = 0.0V$ and $T = [200, 300, 400]K$

Forward output, forced V_{BE} Figure 6.23: Forward output at forced V_{BE} Figure 6.24: Forward output at forced V_{BE}

Forward output, forced I_B

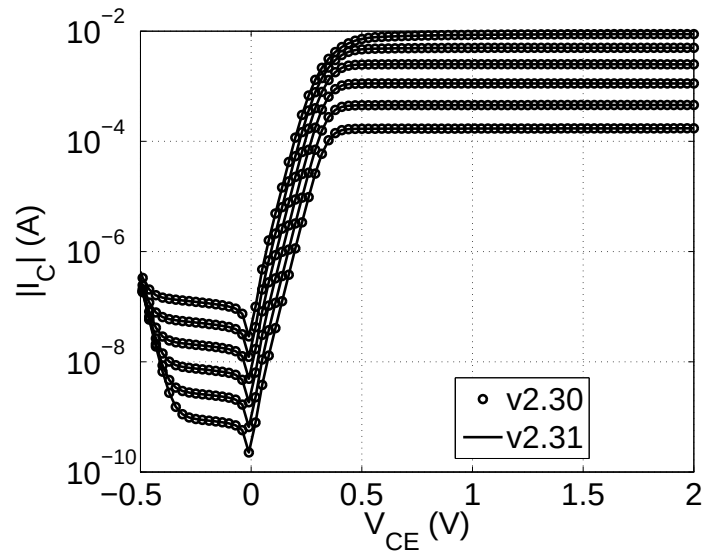


Figure 6.25: Forward output at forced I_B

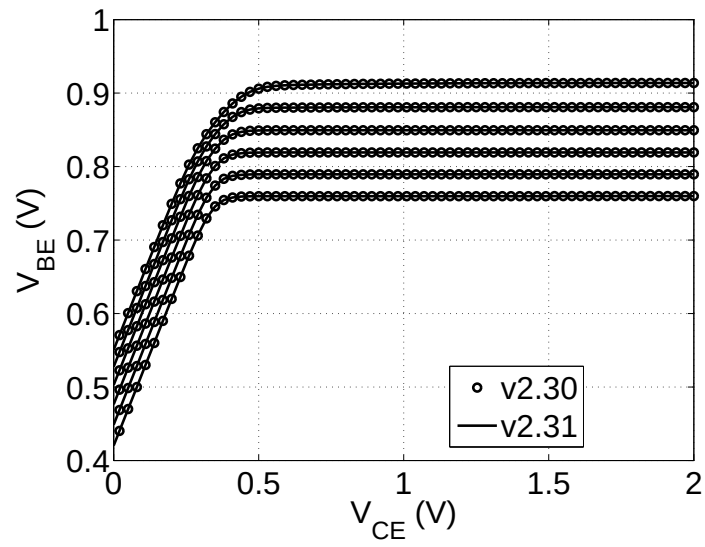


Figure 6.26: Forward output at forced I_B

Small signal results

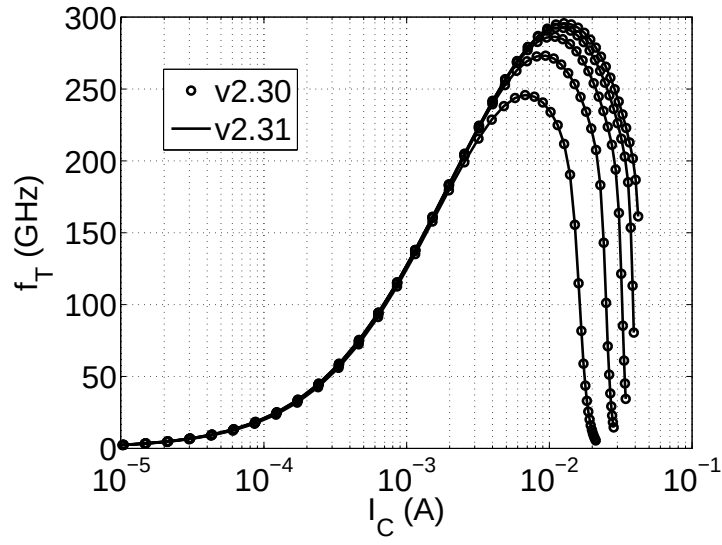


Figure 6.27: Transit frequency versus collector current at room temperature for $V_{BC} = -0.9 \dots 0.3V$

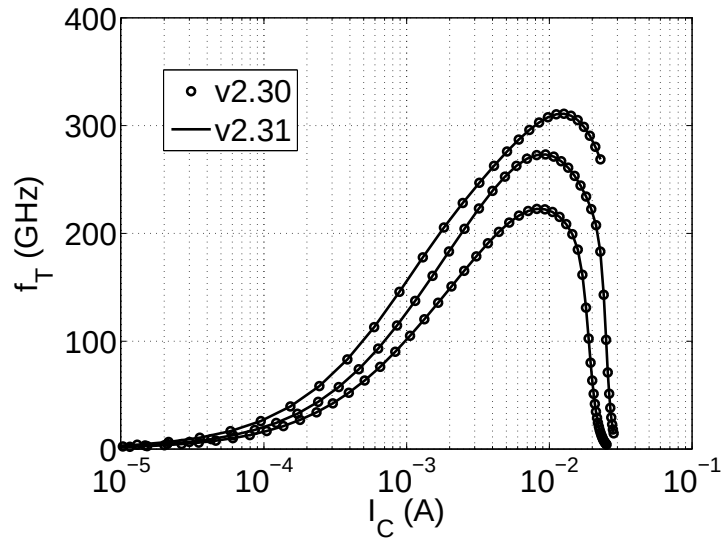


Figure 6.28: Transit frequency versus collector current at $V_{BC} = 0.0V$ and $T = [200, 300, 400]K$

6 Complete transistor including substrate-transistor

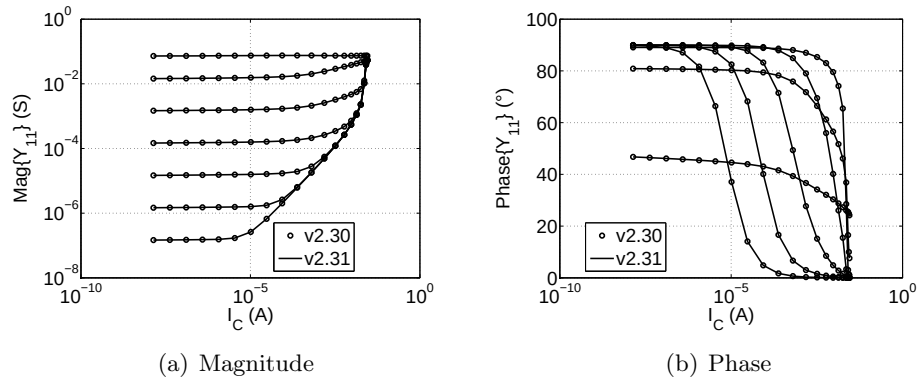


Figure 6.29: Magnitude and phase of Y_{11} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

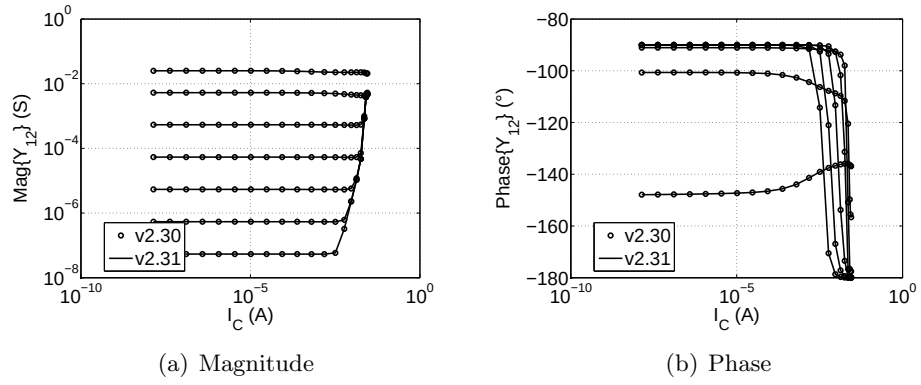


Figure 6.30: Magnitude and phase of Y_{12} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

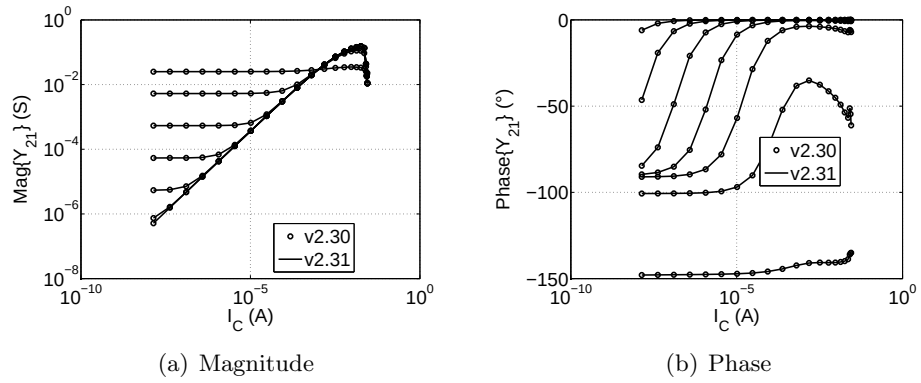


Figure 6.31: Magnitude and phase of Y_{21} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

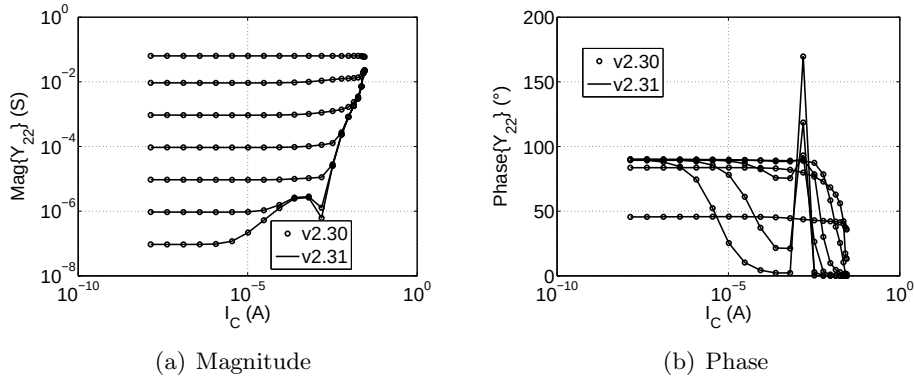


Figure 6.32: Magnitude and phase of Y_{22} versus collector current for $f=1\text{ MHz}\dots 1\text{ THz}$ at $V_{BC} = 0.0V$ and room temperature

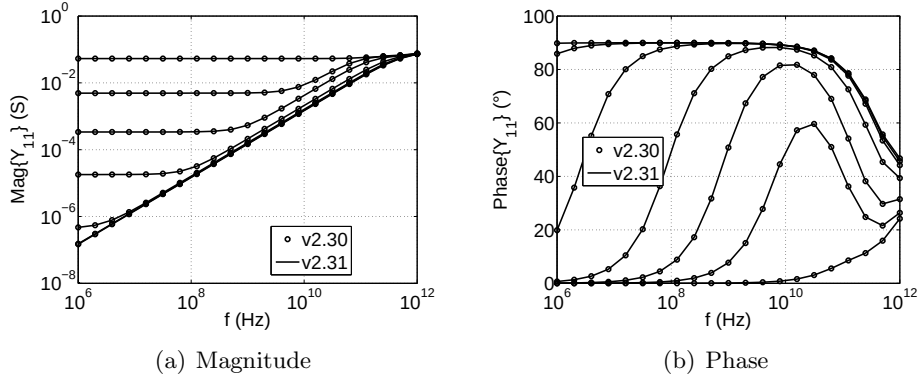


Figure 6.33: Magnitude and phase of Y_{11} versus frequency for $V_{BE} = 0.5\dots 1.1V$ at $V_{BC} = 0.0V$ and room temperature

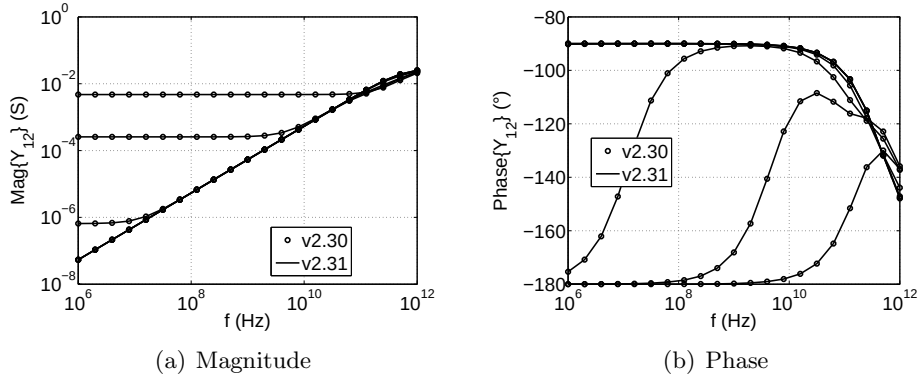


Figure 6.34: Magnitude and phase of Y_{12} versus frequency for $V_{BE} = 0.5\dots 1.1V$ at $V_{BC} = 0.0V$ and room temperature

6 Complete transistor including substrate-transistor

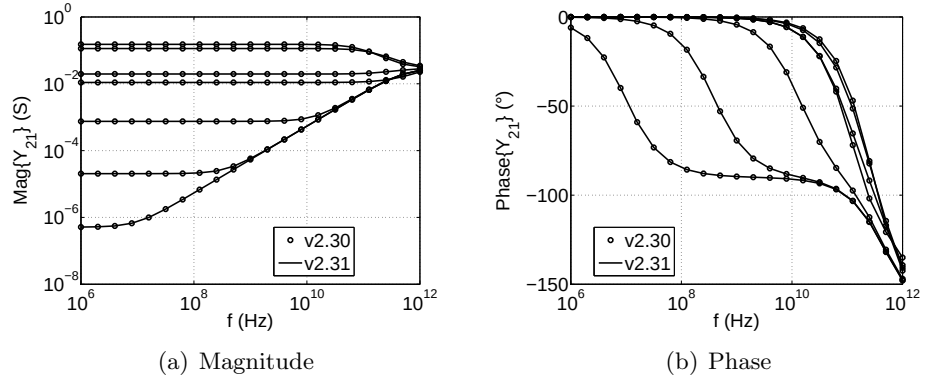


Figure 6.35: Magnitude and phase of Y_{21} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

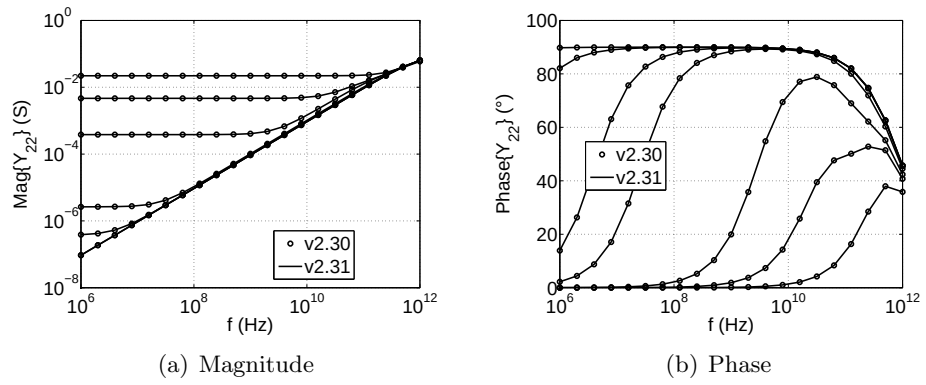


Figure 6.36: Magnitude and phase of Y_{22} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

7 Complete transistor including substrate-transistor and substrate network

7.1 Model cards

7.1.1 Version 2.31, compatible to 2.24

```
c10=2.0175e-032 qp0=2.155e-016 ich=0 hfe=1.8331
hfc=0.05 hjei=0.034883 hjci=0.0026778 ibeis=1.41e-020
mbei=1.012 ireis=1.3583e-015 mrei=2.263 ibeps=1.41e-020
mbep=1.012 ireps=1.3583e-015 mrep=2.263 mcf=1 tbhrec=1e-012
ibcis=5.825e-020 mbci=1.066 ibcx=5.825e-020 mbcx=1.066
ibets=1e-014 abet=40 tunode=1 favl=240.3 qavl=1.1756e-013
alfav=-0.009966 alqav=-0.0009569 rbi0=25 rbx=11 fgeo=0.6557
fdqr0=13 fcrbi=0 fqi=1 re=2.503 rcx=10.55 itss=1e-014
msf=1 iscs=1e-015 msc=1 tsf=0 rsu=200 csu=1e-012
cjei0=4.6632e-015 vdei=0.87043 zei=0.20065 ajei=2.1953
cjep0=4.6632e-015 vdep=0.87043 zep=0.20065 ajep=2.1953
cjci0=3.7096e-015 vdc=0.73351 zci=0.36198 vptci=3.2461 cjc0=0
vdcx=0.7 zcx=0.4 vptcx=100 fbcpar=0 fbepar=1
cjs0=7.06e-015 vds=0.6 zs=0.17 vpts=100 t0=2.2784e-013
dt0h=1.0591e-013 tbvl=1.5456e-014 tef0=4.4727e-013 gtfe=1.4744
thcs=1e-011 ahc=0.06 fthc=0.5 rci0=19.44 vlim=1.429
vces=0.001 vpt=18 tr=0 cbepar=3.81e-015 cbcpar=4.86e-015
alqf=0.16667 alit=0.33333 flnqs=0 kf=0 af=2 cfbe=-1 latb=0
latl=0 vgb=0.9 alt0=0.0025354 kt0=1e-005 zetaci=0.5621
alvs=0.00217 alces=-0.00584 zetarbi=0 zetarbx=0 zetarcx=0.191
zetare=0.2042 zetacx=-3.2 vge=1.17 vgc=1.17 vgs=0.807
f1vg=-0.00010238 f2vg=0.00043215 zetact=5.3125 zetabet=1.3855
alb=0 flsh=0 rth=0 cth=0 flcomp=2.2 tnom=27 dt=0
zetarth=0 type=1 flcono=0
```

7.1.2 Version 2.31, compatible to 2.30

```
c10=2.0175e-032 qp0=2.155e-016 ich=0 hfe=1.8331
hfc=0.05 hjei=0.034883 hjci=0.0026778 ibeis=1.41e-020
mbei=1.012 ireis=1.3583e-015 mrei=2.263 ibeps=1.41e-020
```

7 Complete transistor including substrate-transistor and substrate network

mbep=1.012 ireps=1.3583e-015 mrep=2.263 mcf=1 tbhrec=1e-012
ibcis=5.825e-020 mbci=1.066 ibcx=5.825e-020 mbcx=1.066
ibets=1e-014 abet=40 tunode=1 favl=240.3 qavl=1.1756e-013
alfav=-0.009966 alqav=-0.0009569 rbi0=25 rbx=11 fgeo=0.6557
fdqr0=13 fcrbi=0 fqi=1 re=2.503 rcx=10.55 itss=1e-014
msf=1 iscs=1e-015 msc=1 tsf=0 rsu=200 csu=1e-012
cjei0=4.6632e-015 vdei=0.87043 zei=0.20065 ajei=2.1953
cjep0=4.6632e-015 vdep=0.87043 zep=0.20065 ajep=2.1953
cjci0=3.7096e-015 vdc=0.73351 zci=0.36198 vptci=3.2461 cjc0=0
vdcx=0.7 zcx=0.4 vptcx=100 fbcpar=0 fbepar=1
cjs0=7.06e-015 vds=0.6 zs=0.17 vpts=100 t0=2.2784e-013
dt0h=1.0591e-013 tbvl=1.5456e-014 tef0=4.4727e-013 gtfe=1.4744
thcs=1e-011 ahc=0.06 fthc=0.5 rci0=19.44 vlim=1.429
vces=0.001 vpt=18 tr=0 cbepar=3.81e-015 cbcpar=4.86e-015
alqf=0.16667 alit=0.33333 flnqs=0 kf=0 af=2 cfbe=-1 latb=0
latl=0 vgb=0.9 alt0=0.0025354 kt0=1e-005 zetaci=0.5621
alvs=0.00217 alces=-0.00584 zetarbi=0 zetarbx=0 zetarcx=0.191
zetare=0.2042 zetacx=-3.2 vge=1.17 vgc=1.17 vgs=0.807
f1vg=-0.00010238 f2vg=0.00043215 zetact=5.3125 zetabet=1.3855
alb=0 flsh=0 rth=0 cth=0 flcomp=2.3 tnom=27 dt=0
zetarth=0 type=1 flcono=0 hf0=0.24679 ahjei=5.912 rhjei=2
vcbar=0.04 icbar=0.003 acbar=1.5 delck=1.8 dvgbe=-0.1103
zetahjei=-0.78133 zetavgbe=0.7 alrth=0

7.2 Simulation results

7.2.1 Comparison between version 2.31 and 2.24

Forward gummel

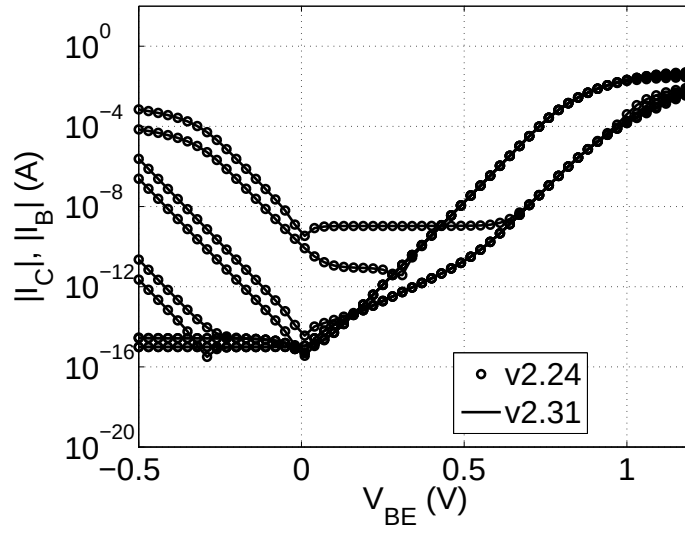


Figure 7.1: Forward gummel at room temperature for $V_{BC} = -0.9 \dots 0.3V$

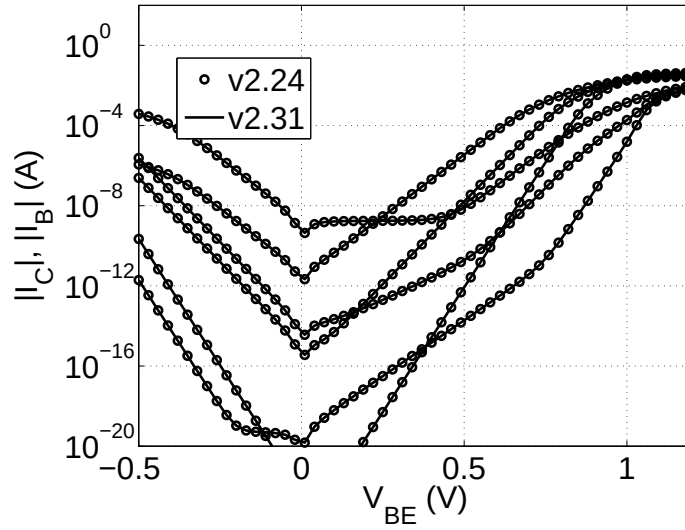


Figure 7.2: Forward gummel at $V_{BC} = 0.0V$ and $T = [200, 300, 400]K$

Reverse gummel

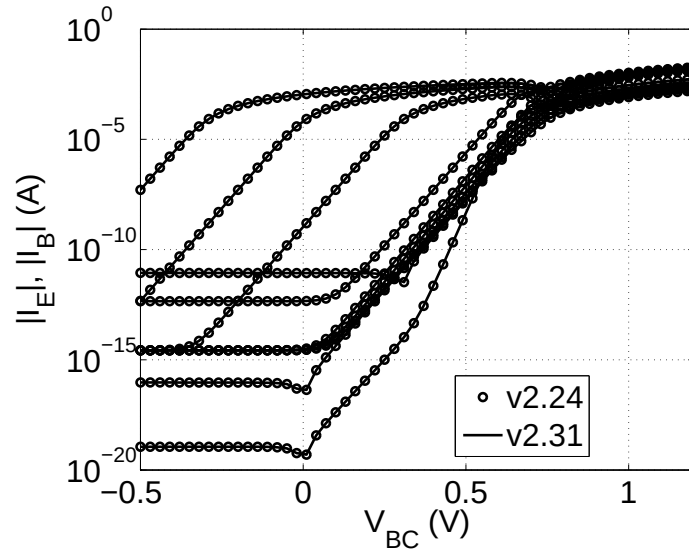


Figure 7.3: Reverse gummel at room temperature for $V_{BE} = -0.9...0.3V$

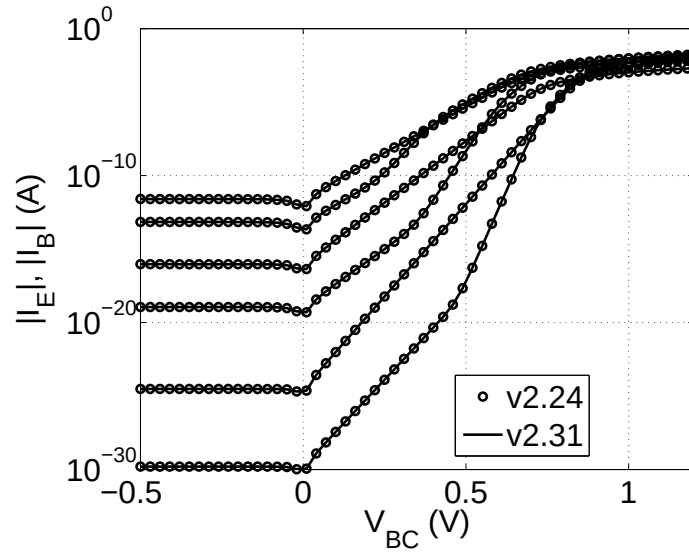
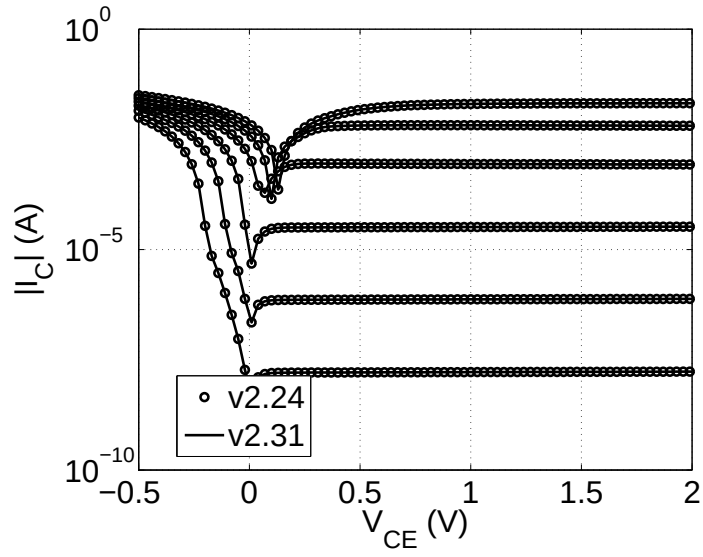
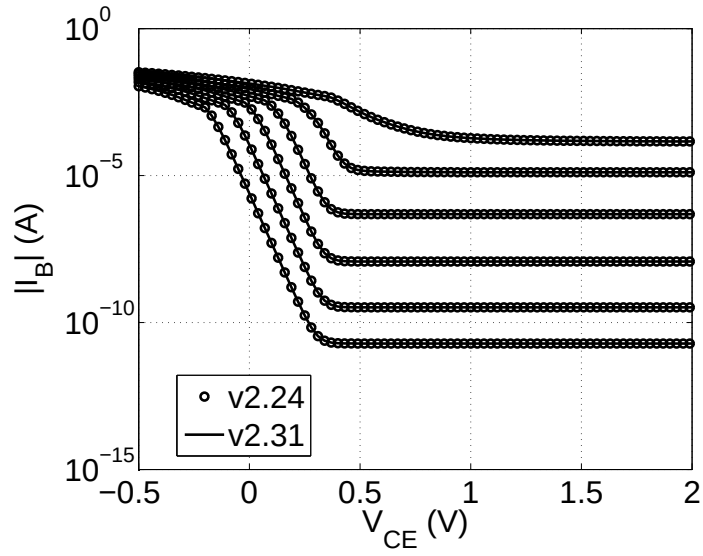


Figure 7.4: Reverse gummel at $V_{BE} = 0.0V$ and $T = [200, 300, 400]K$

Forward output, forced V_{BE} Figure 7.5: Forward output at forced V_{BE} Figure 7.6: Forward output at forced V_{BE}

Forward output, forced I_B

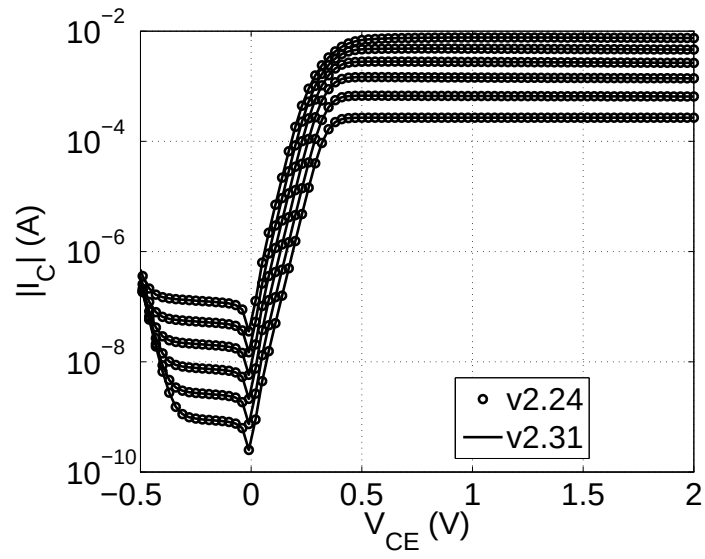


Figure 7.7: Forward output at forced I_B

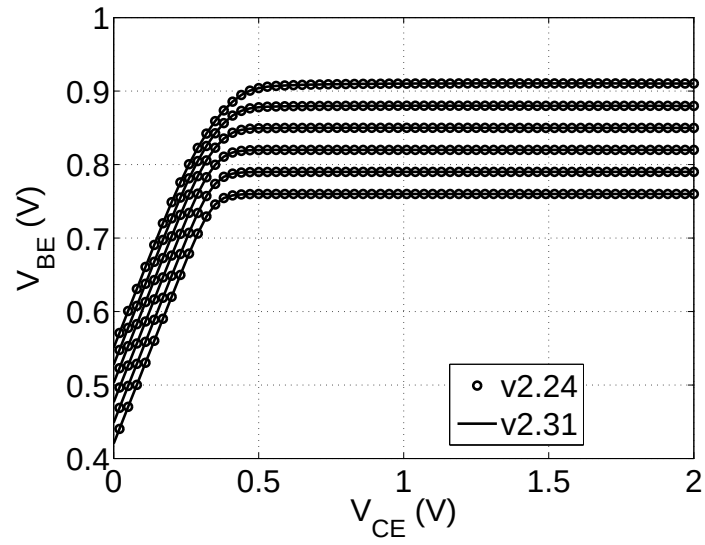


Figure 7.8: Forward output at forced I_B

Small signal results

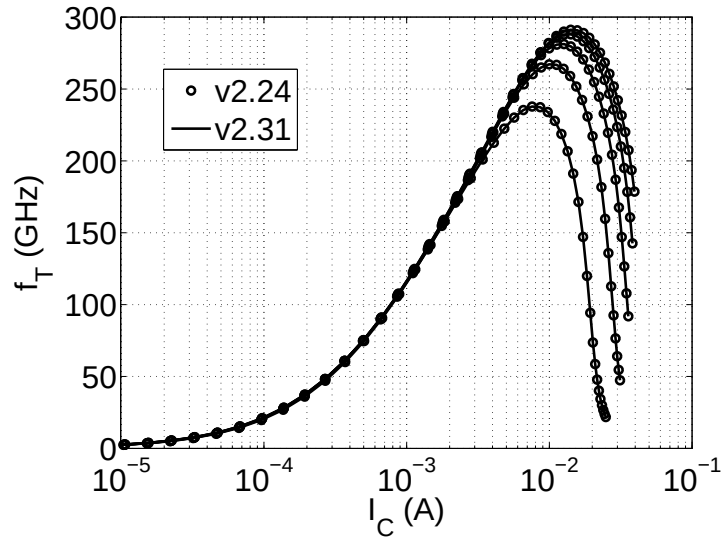


Figure 7.9: Transit frequency versus collector current at room temperature for $V_{BC} = -0.9 \dots 0.3V$

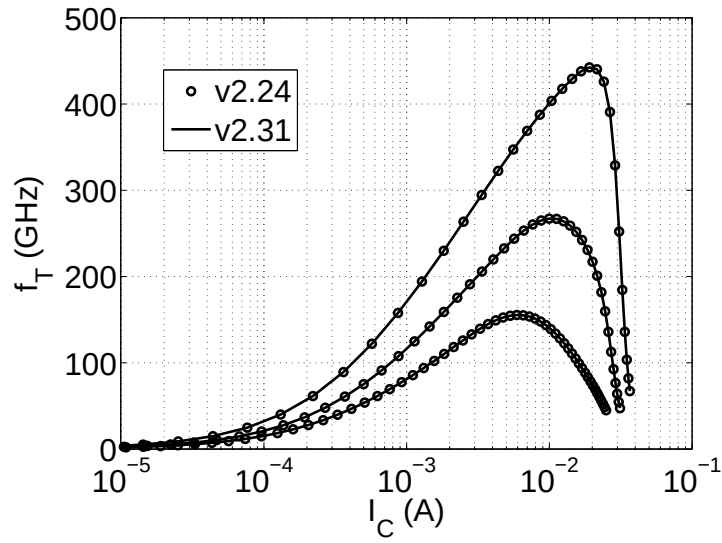


Figure 7.10: Transit frequency versus collector current at $V_{BC} = 0.0V$ and $T = [200, 300, 400]K$

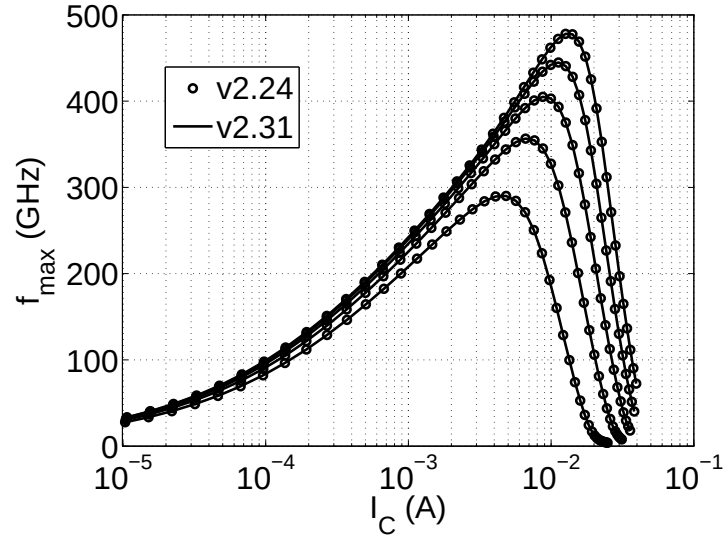


Figure 7.11: Maximum oscillation frequency versus collector current at room temperature for $V_{BC} = -0.9...0.3V$

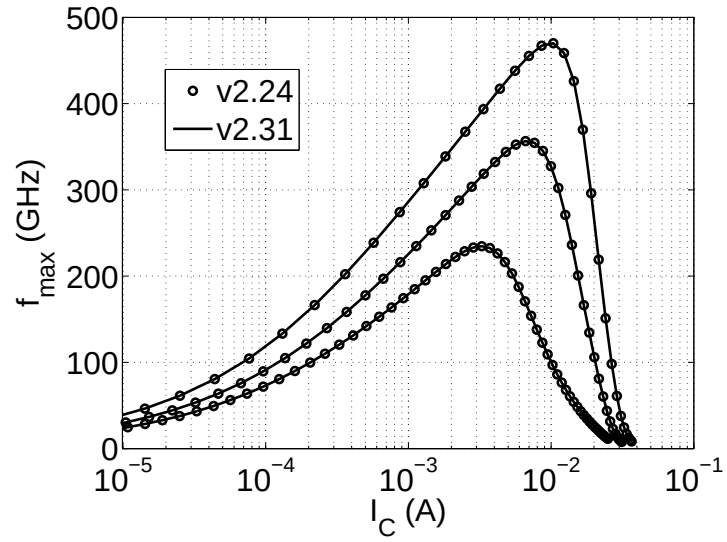


Figure 7.12: Maximum oscillation frequency versus collector current at $V_{BC} = 0.0V$ and $T = [200, 300, 400]K$

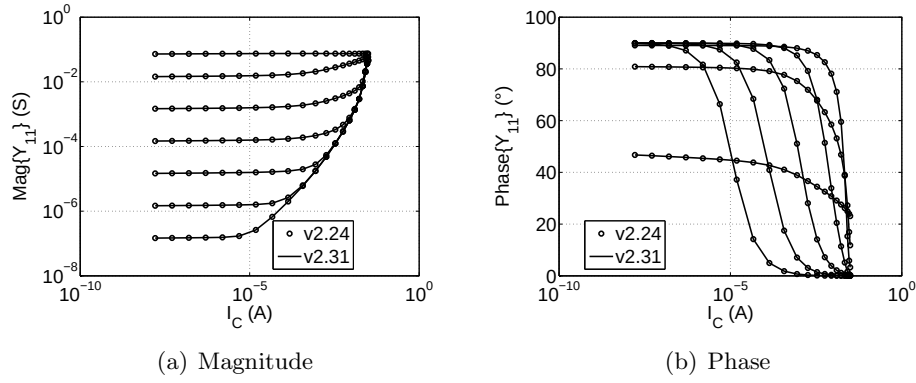


Figure 7.13: Magnitude and phase of Y_{11} versus collector current for $f=1\text{ MHz}\dots 1\text{ THz}$ at $V_{BC} = 0.0V$ and room temperature

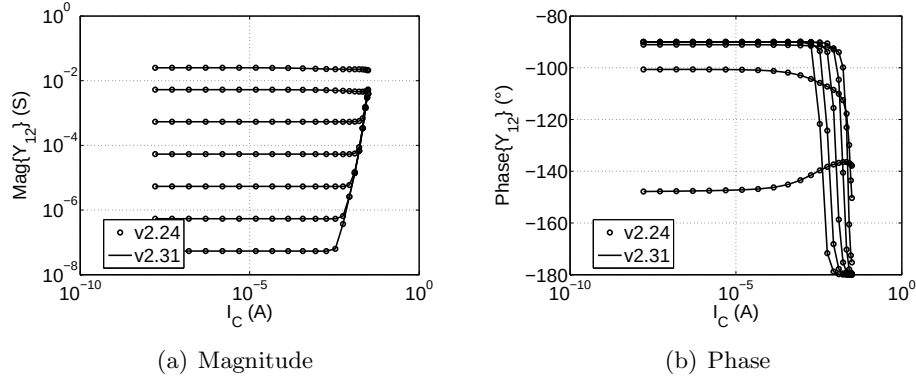


Figure 7.14: Magnitude and phase of Y_{12} versus collector current for $f=1\text{ MHz}\dots 1\text{ THz}$ at $V_{BC} = 0.0V$ and room temperature

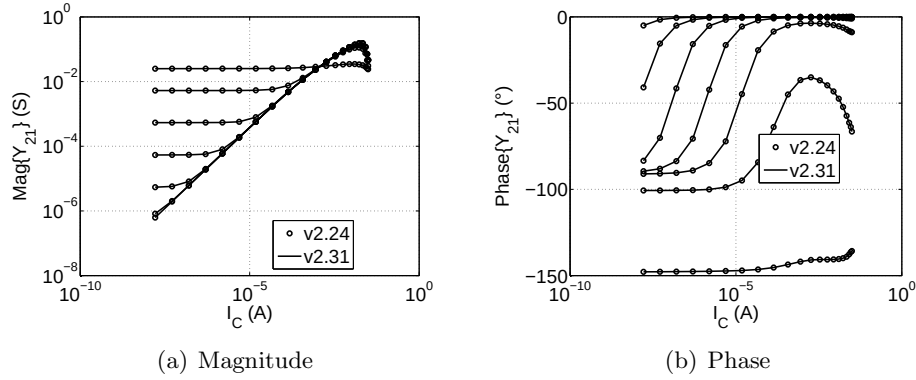


Figure 7.15: Magnitude and phase of Y_{21} versus collector current for $f=1\text{ MHz}\dots 1\text{ THz}$ at $V_{BC} = 0.0V$ and room temperature

7 Complete transistor including substrate-transistor and substrate network

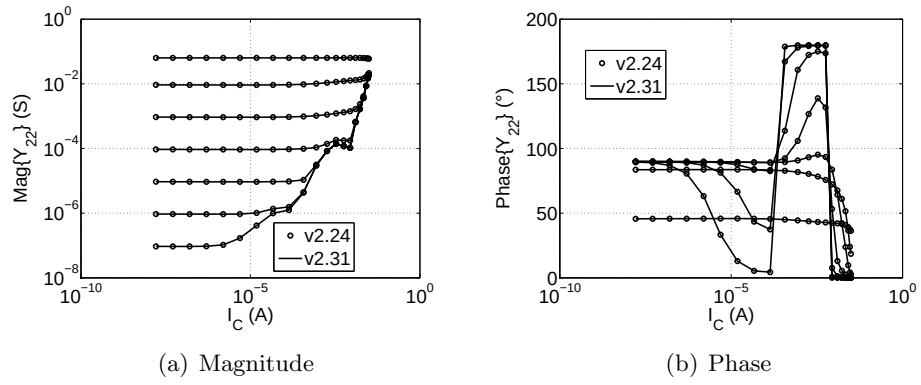


Figure 7.16: Magnitude and phase of Y_{22} versus collector current for $f=1\text{ MHz}\dots 1\text{ THz}$ at $V_{BC} = 0.0\text{V}$ and room temperature

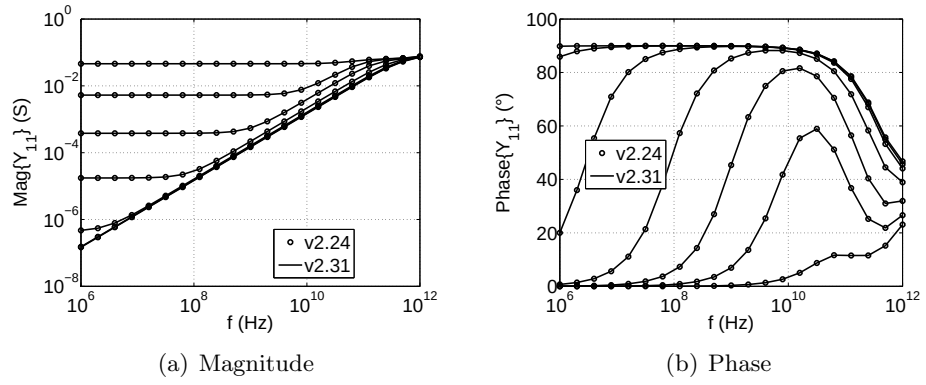


Figure 7.17: Magnitude and phase of Y_{11} versus frequency for $V_{BE} = 0.5\dots 1.1\text{V}$ at $V_{BC} = 0.0\text{V}$ and room temperature

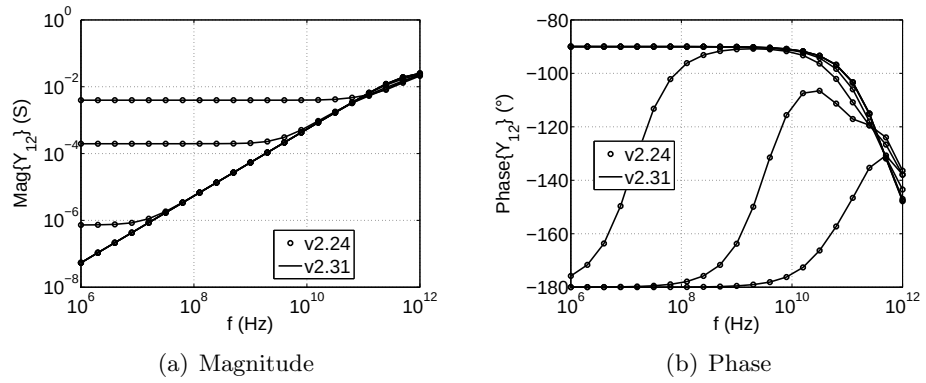


Figure 7.18: Magnitude and phase of Y_{12} versus frequency for $V_{BE} = 0.5\dots 1.1\text{V}$ at $V_{BC} = 0.0\text{V}$ and room temperature

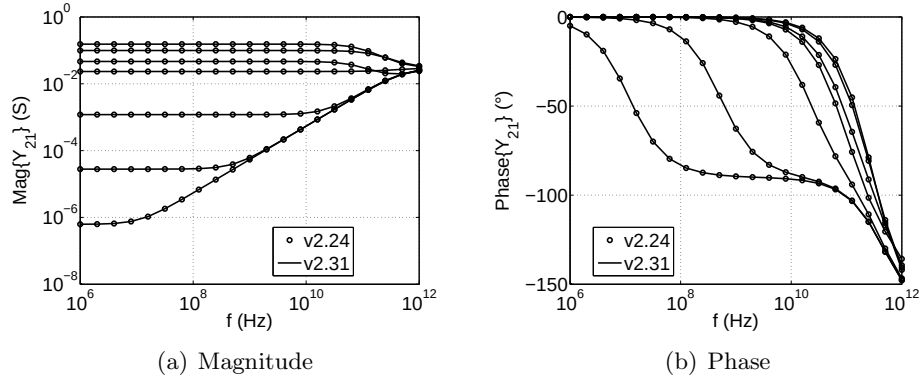


Figure 7.19: Magnitude and phase of Y_{21} versus frequency for $V_{BE} = 0.5 \dots 1.1V$ at $V_{BC} = 0.0V$ and room temperature

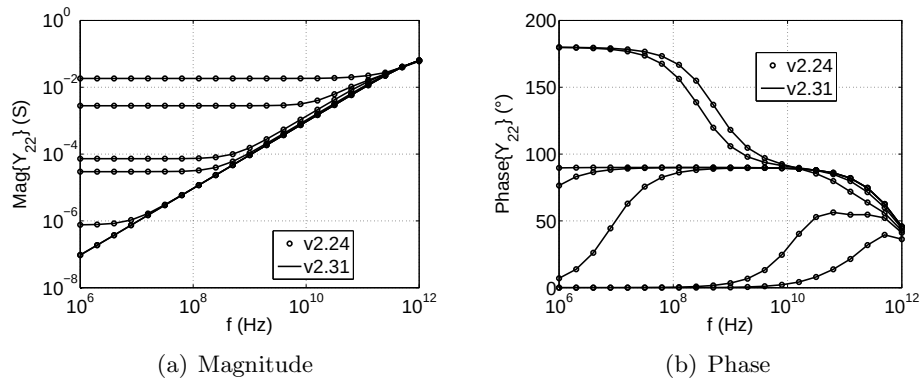


Figure 7.20: Magnitude and phase of Y_{22} versus frequency for $V_{BE} = 0.5 \dots 1.1V$ at $V_{BC} = 0.0V$ and room temperature

7.2.2 Comparison between version 2.31 and 2.30

Forward gummel

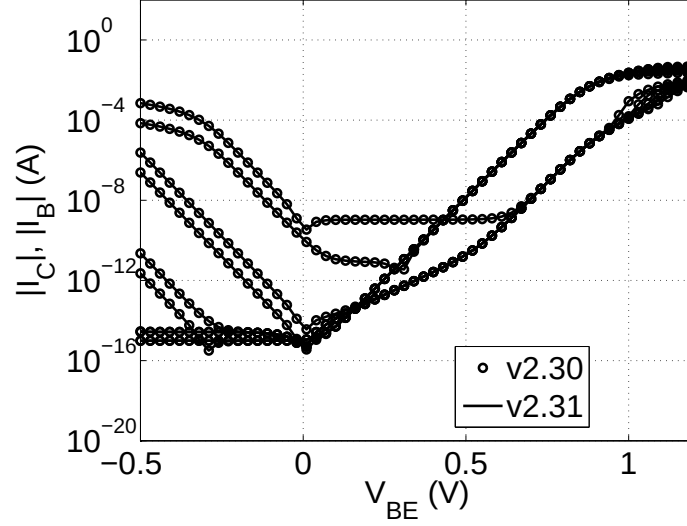


Figure 7.21: Forward gummel at room temperature for $V_{BC} = -0.9...0.3V$

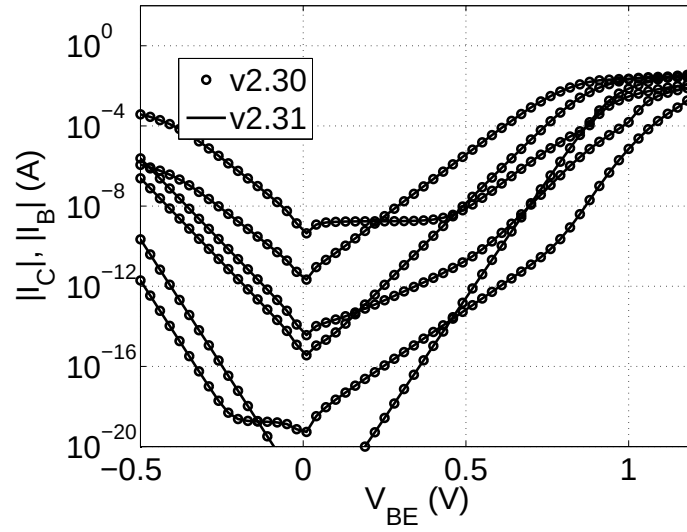
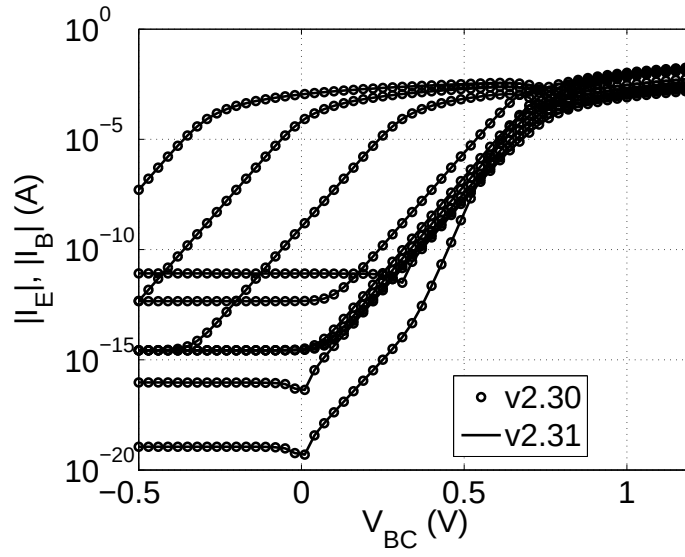
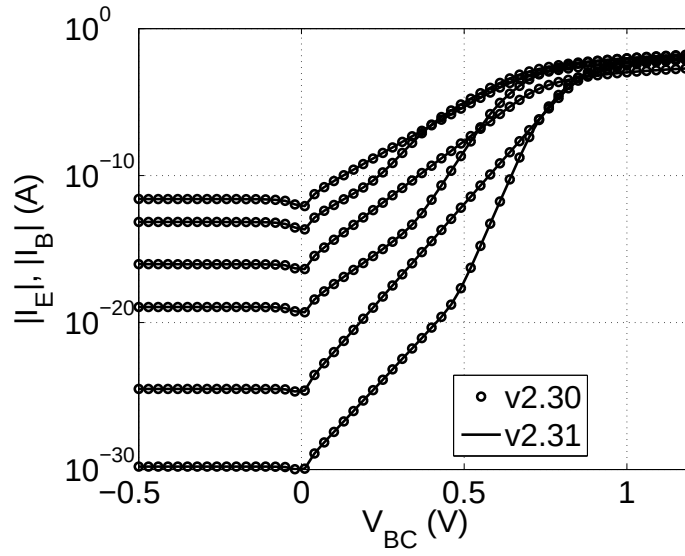


Figure 7.22: Forward gummel at $V_{BC} = 0.0V$ and $T = [200, 300, 400]K$

Reverse gummel

Figure 7.23: Reverse gummel at room temperature for $V_{BE} = -0.9...0.3V$ Figure 7.24: Reverse gummel at $V_{BE} = 0.0V$ and $T = [200, 300, 400]K$

Forward output, forced V_{BE}

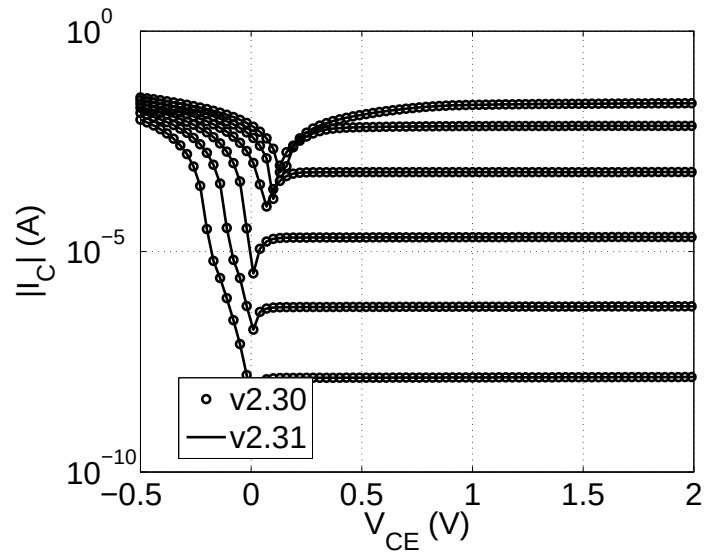


Figure 7.25: Forward output at forced V_{BE}

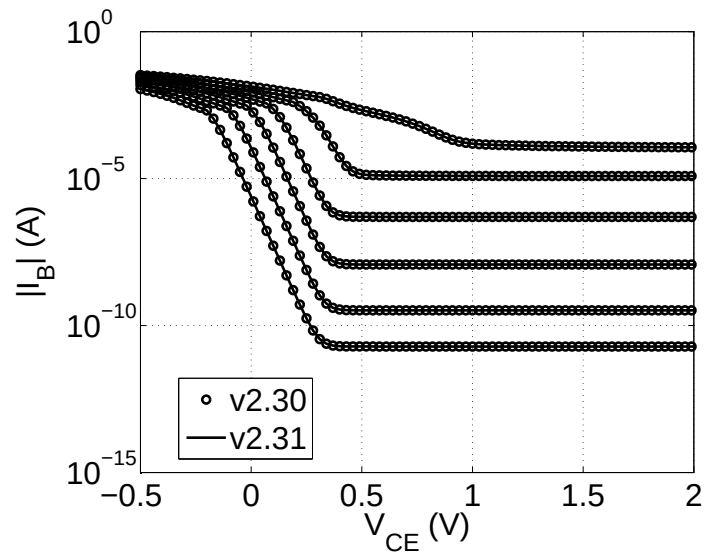
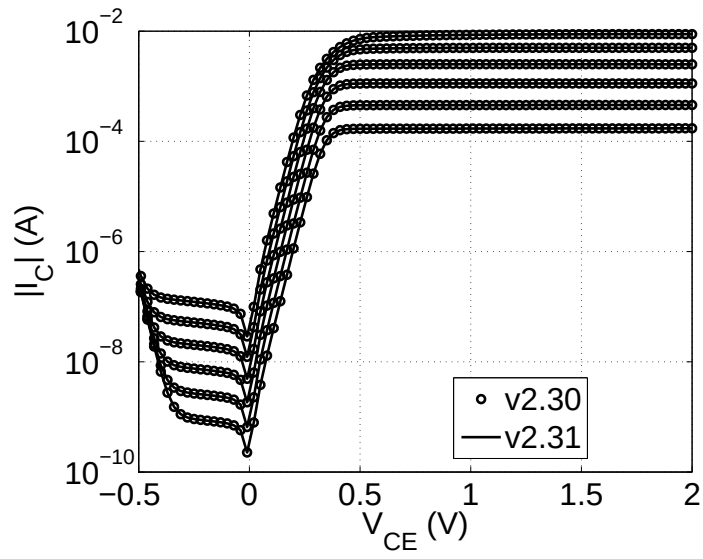
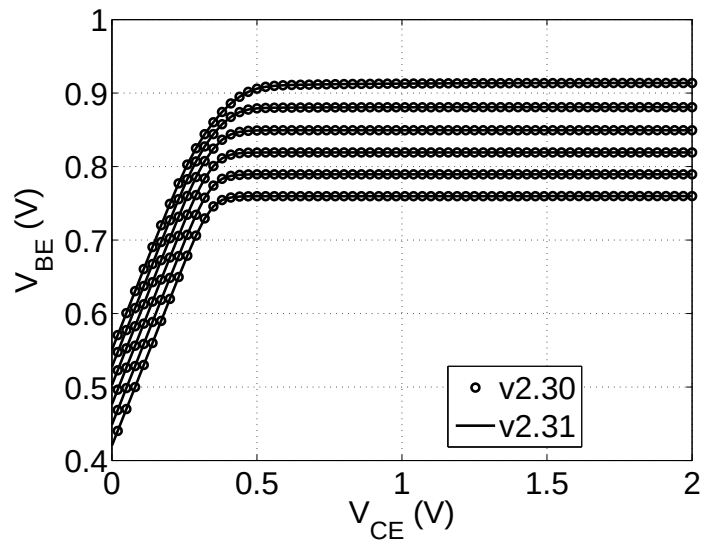


Figure 7.26: Forward output at forced V_{BE}

Forward output, forced I_B Figure 7.27: Forward output at forced I_B Figure 7.28: Forward output at forced I_B

Small signal results

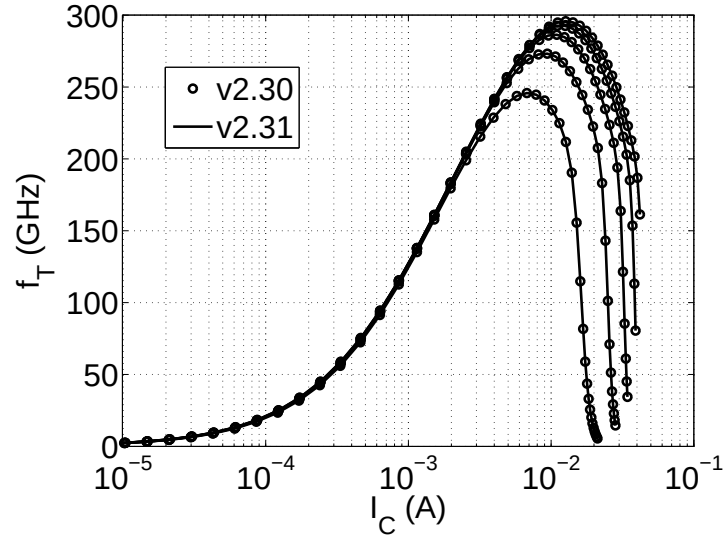


Figure 7.29: Transit frequency versus collector current at room temperature for $V_{BC} = -0.9...0.3V$

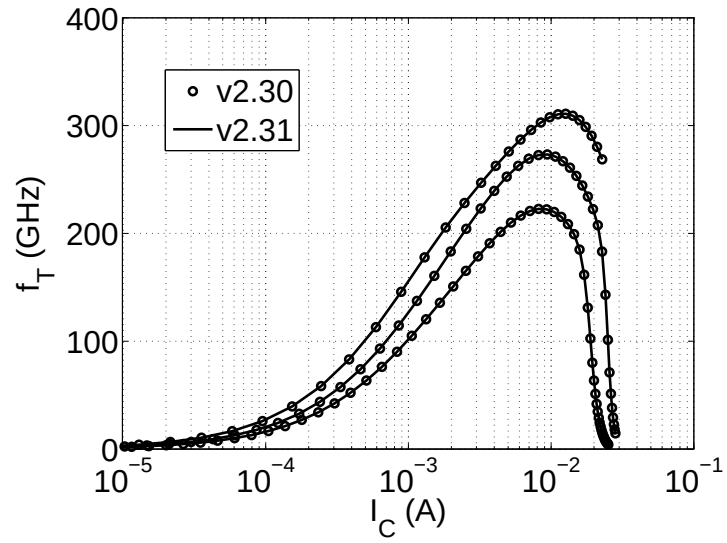


Figure 7.30: Transit frequency versus collector current at $V_{BC} = 0.0V$ and $T = [200, 300, 400]K$

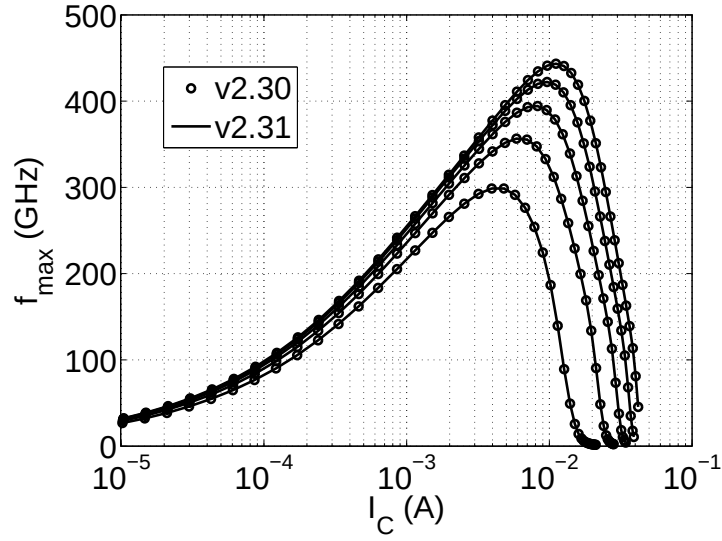


Figure 7.31: Maximum oscillation frequency versus collector current at room temperature for $V_{BC} = -0.9...0.3V$

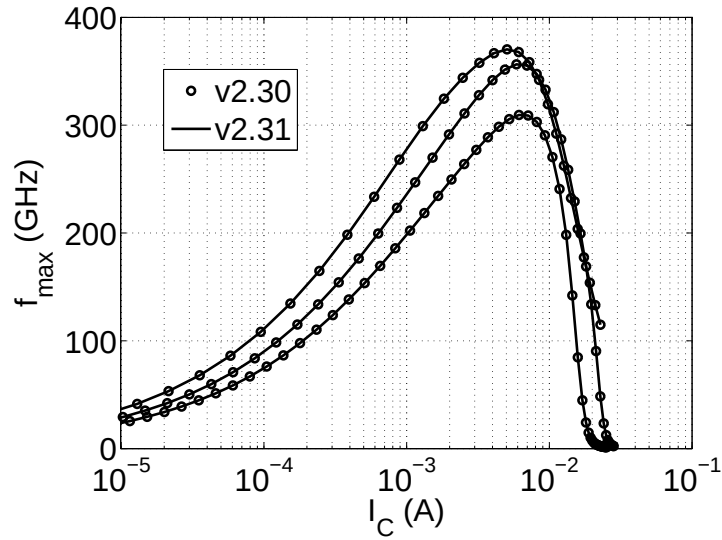


Figure 7.32: Maximum oscillation frequency versus collector current at $V_{BC} = 0.0V$ and $T = [200, 300, 400]K$

7 Complete transistor including substrate-transistor and substrate network

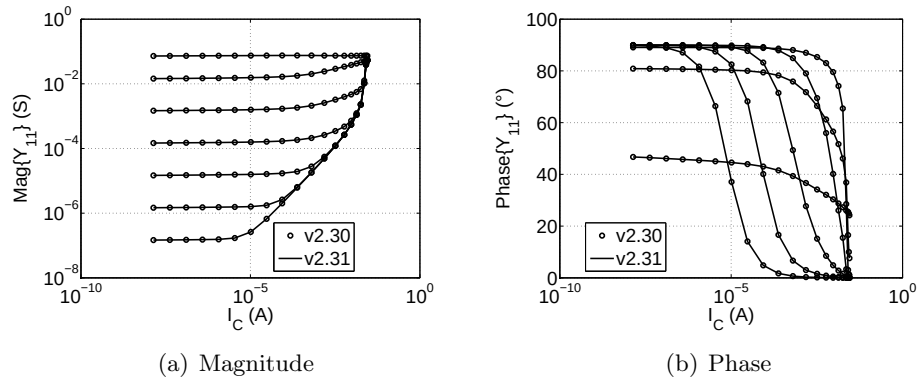


Figure 7.33: Magnitude and phase of Y_{11} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

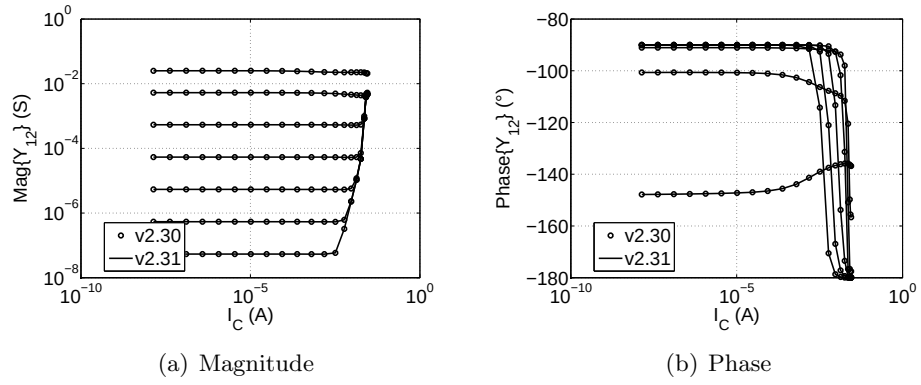


Figure 7.34: Magnitude and phase of Y_{12} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

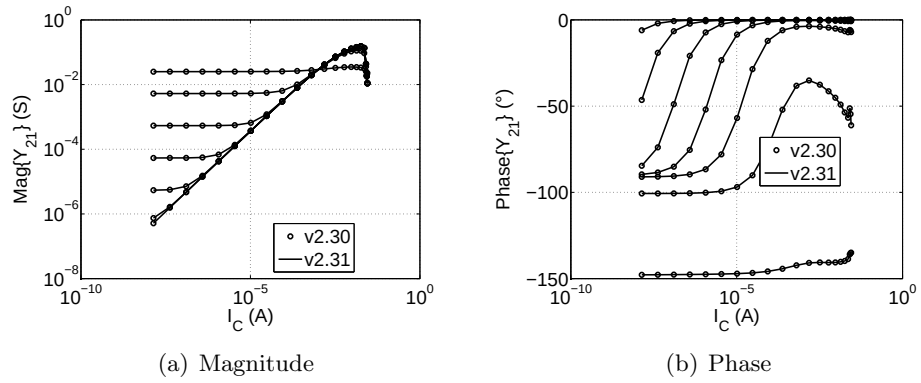


Figure 7.35: Magnitude and phase of Y_{21} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

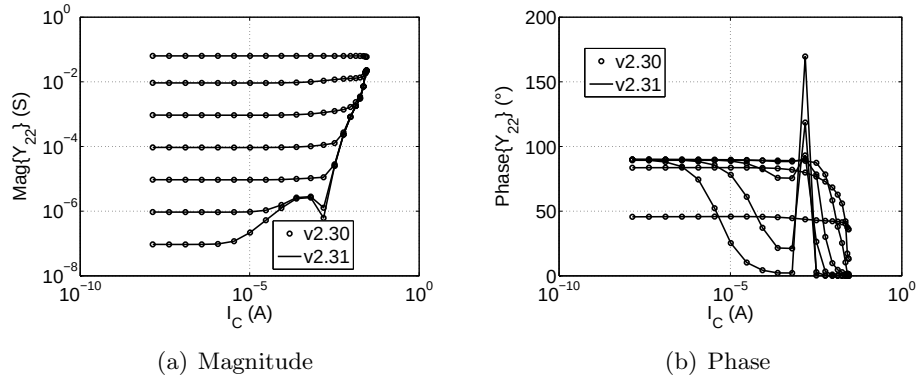


Figure 7.36: Magnitude and phase of Y_{22} versus collector current for $f=1\text{ MHz} \dots 1\text{ THz}$ at $V_{BC} = 0.0\text{V}$ and room temperature

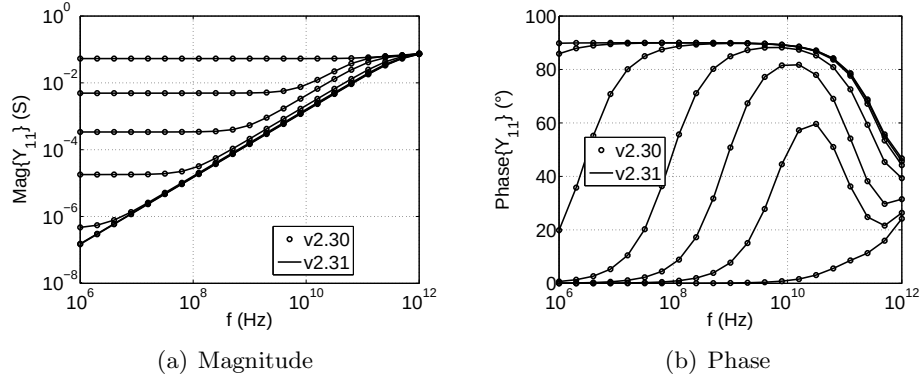


Figure 7.37: Magnitude and phase of Y_{11} versus frequency for $V_{BE} = 0.5 \dots 1.1\text{V}$ at $V_{BC} = 0.0\text{V}$ and room temperature

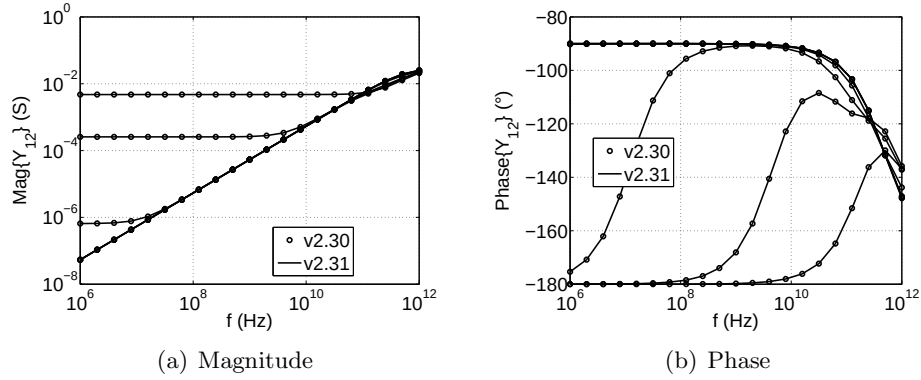


Figure 7.38: Magnitude and phase of Y_{12} versus frequency for $V_{BE} = 0.5 \dots 1.1\text{V}$ at $V_{BC} = 0.0\text{V}$ and room temperature

7 Complete transistor including substrate-transistor and substrate network

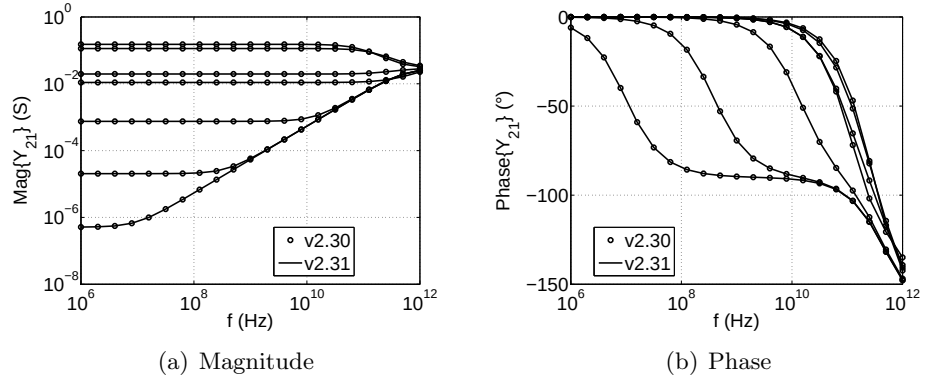


Figure 7.39: Magnitude and phase of Y_{21} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

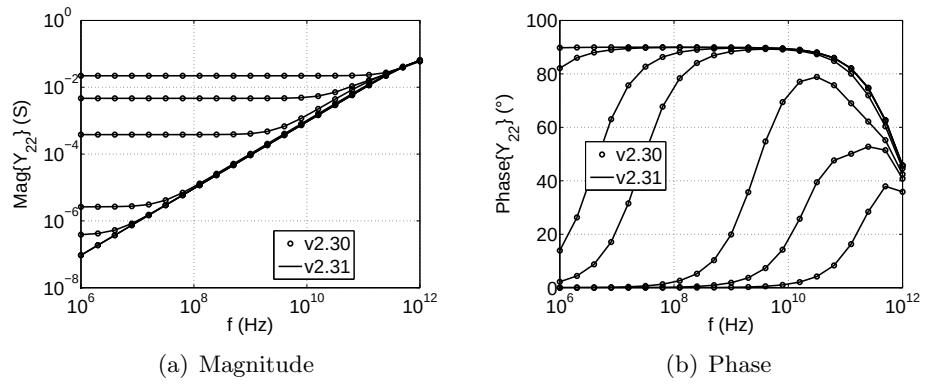


Figure 7.40: Magnitude and phase of Y_{22} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

8 1D Transistor including vertical NQS-effects

Since for this model card only small signal parameters are effected, no DC curves are shown here.

8.1 Model cards

8.1.1 Version 2.31, compatible to 2.24

```
c10=2.0175e-032 qp0=2.155e-016 ich=0 hfe=1.8331
hfc=0.05 hjei=0.034883 hjci=0.0026778 ibeis=2.82e-020
mbei=1.012 ireis=2.7167e-015 mrei=2.263 ibeps=0 mbep=1
ireps=0 mrep=2 mcf=1 tbhrec=1e-012 ibcis=1.165e-019
mbci=1.066 ibcx=0 mbcx=1 ibets=0 abet=40 tunode=1
favl=240.3 qavl=1.1756e-013 alfav=-0.009966 alqav=-0.0009569
rbi0=0 rbx=0 fgeo=0.6557 fdqr0=0 fcrbi=0 fqi=1 re=0
rcx=0 itss=0 msf=1 iscs=0 msc=1 tsf=0 rsu=0 csu=0
cjei0=9.3264e-015 vdei=0.87043 zei=0.20065 ajei=2.1953 cjep0=1e-020
vdep=0.9 zep=0.5 ajep=2.5 cjci0=7.4192e-015 vdc=0.73351
zci=0.36198 vptci=3.2461 cjc0=1e-020 vdcx=0.7 zcx=0.4
vptcx=100 fbcpar=0 fbepar=1 cjs0=0 vds=0.6 zs=0.5 vpts=100
t0=2.2784e-013 dt0h=1.0591e-013 tbvl=1.5456e-014
tef0=4.4727e-013 gtfe=1.4744 thcs=1e-011 ahc=0.06 fthc=0.5
rci0=19.44 vlim=1.429 vces=0.001 vpt=18 tr=0 cbepar=0
cbcp=0 alqf=0.167 alit=0.33 flnqs=1 kf=0 af=2 cfbe=-1
latb=0 latl=0 vgb=0.9 alt0=0.0025354 kt0=1e-005
zetaci=0.5621 alvs=0.00217 alces=-0.00584 zetarbi=0 zetarbx=0
zetarcx=0 zetare=0 zetacx=1 vge=1.17 vgc=1.17 vgs=1.17
f1vg=-0.00010238 f2vg=0.00043215 zetact=5.3125 zetabet=1.3855
alb=0 flsh=0 rth=0 cth=0 flcomp=2.2 tnom=27 dt=0
zetarth=0 type=1 flcono=0
```

8.1.2 Version 2.31, compatible to 2.30

```
c10=2.0175e-032 qp0=2.155e-016 ich=0 hfe=1.8331
hfc=0.05 hjei=0.034883 hjci=0.0026778 ibeis=2.82e-020
mbei=1.012 ireis=2.7167e-015 mrei=2.263 ibeps=0 mbep=1
```

```

ireps=0 mrep=2 mcf=1 tbhrec=1e-012 ibcis=1.165e-019
mbci=1.066 ibcx=0 mbcx=1 ibets=0 abet=40 tunode=1
favl=240.3 qavl=1.1756e-013 alfav=-0.009966 alqav=-0.0009569
rbi0=0 rbx=0 fgeo=0.6557 fdqr0=0 fcrbi=0 fqi=1 re=0
rcx=0 itss=0 msf=1 iscs=0 msc=1 tsf=0 rsu=0 csu=0
cjei0=9.3264e-015 vdei=0.87043 zei=0.20065 ajei=2.1953 cjep0=1e-020
vdep=0.9 zep=0.5 ajep=2.5 cjci0=7.4192e-015 vdc=0.73351
zci=0.36198 vptci=3.2461 cjc0=1e-020 vdcx=0.7 zcx=0.4
vptcx=100 fbcpar=0 fbepar=1 cjs0=0 vds=0.6 zs=0.5 vpts=100
t0=2.2784e-013 dt0h=1.0591e-013 tbvl=1.5456e-014
tef0=4.4727e-013 gtfe=1.4744 thcs=1e-011 ahc=0.06 fthc=0.5
rci0=19.44 vlim=1.429 vces=0.001 vpt=18 tr=0 cbepar=0
cbcp=0 alqf=0.167 alit=0.33 flnqs=1 kf=0 af=2 cfbe=-1
latb=0 latl=0 vgb=0.9 alt0=0.0025354 kt0=1e-005
zetaci=0.5621 alvs=0.00217 alces=-0.00584 zetarbi=0 zetarbx=0
zetarcx=0 zetare=0 zetacx=1 vge=1.17 vgc=1.17 vgs=1.17
flvg=-0.00010238 f2vg=0.00043215 zetact=5.3125 zetabet=1.3855
alb=0 flsh=0 rth=0 cth=0 flcomp=2.3 tnom=27 dt=0
zeth=0 type=1 flcono=0 hf0=0.24679 ahjei=5.912 rhjei=2
vbar=0.04 icbar=0.003 acbar=1.5 delck=1.8 dvgbe=-0.1103
zetahjei=-0.78133 zetavgbe=0.7 alrth=0

```

8.2 Simulation results

8.2.1 Comparison between version 2.31 and 2.24

Small signal results

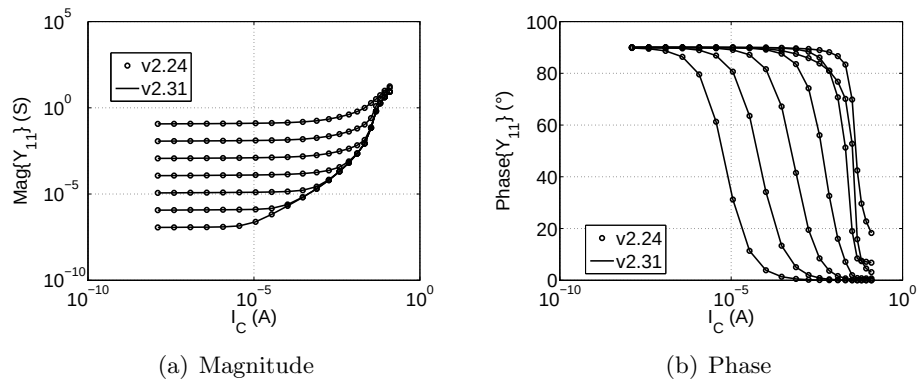


Figure 8.1: Magnitude and phase of Y_{11} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

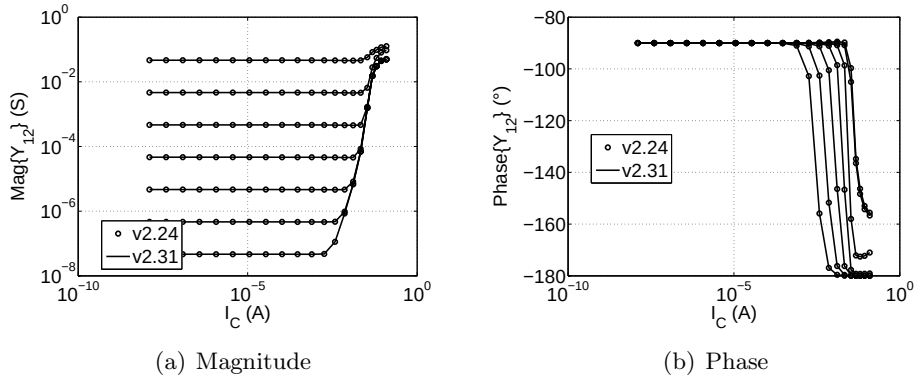


Figure 8.2: Magnitude and phase of Y_{12} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

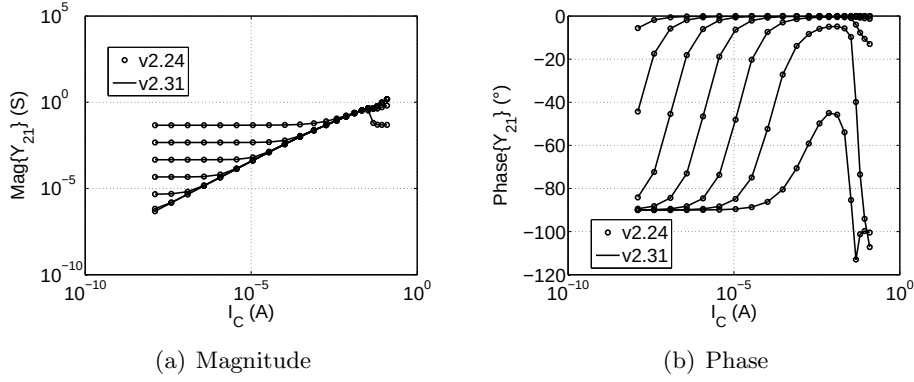


Figure 8.3: Magnitude and phase of Y_{21} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

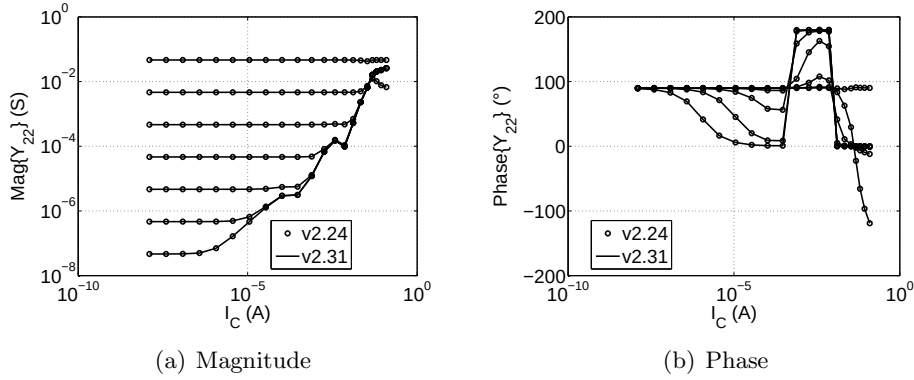


Figure 8.4: Magnitude and phase of Y_{22} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

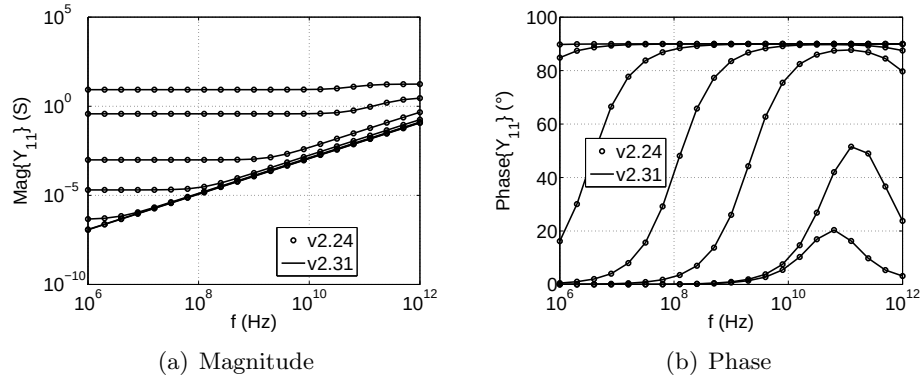


Figure 8.5: Magnitude and phase of Y_{11} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

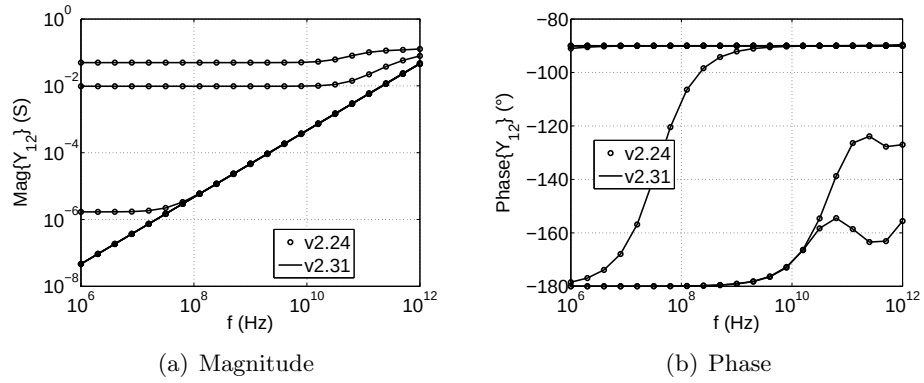


Figure 8.6: Magnitude and phase of Y_{12} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

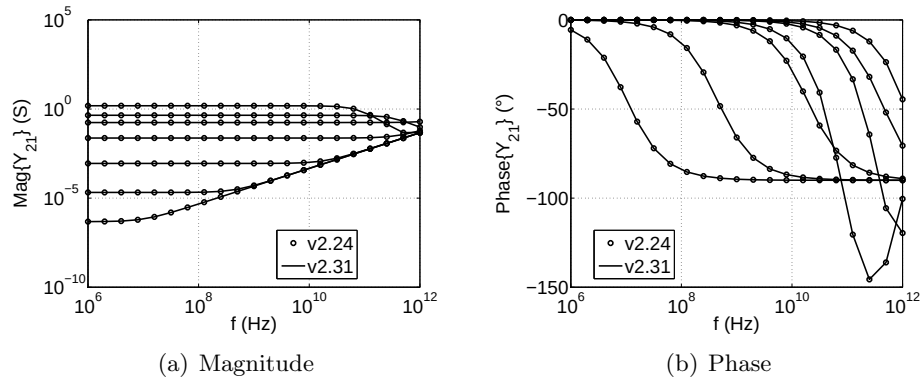


Figure 8.7: Magnitude and phase of Y_{21} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

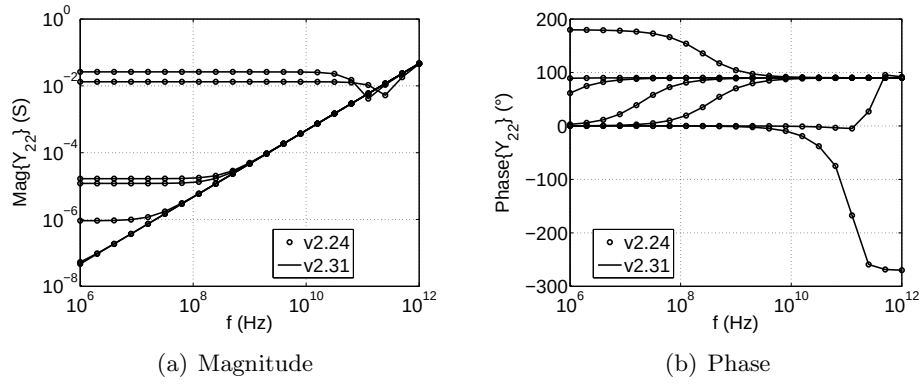


Figure 8.8: Magnitude and phase of Y_{22} versus frequency for $V_{BE} = 0.5 \dots 1.1 \text{ V}$ at $V_{BC} = 0.0 \text{ V}$ and room temperature

8.2.2 Comparison between version 2.31 and 2.30

Small signal results

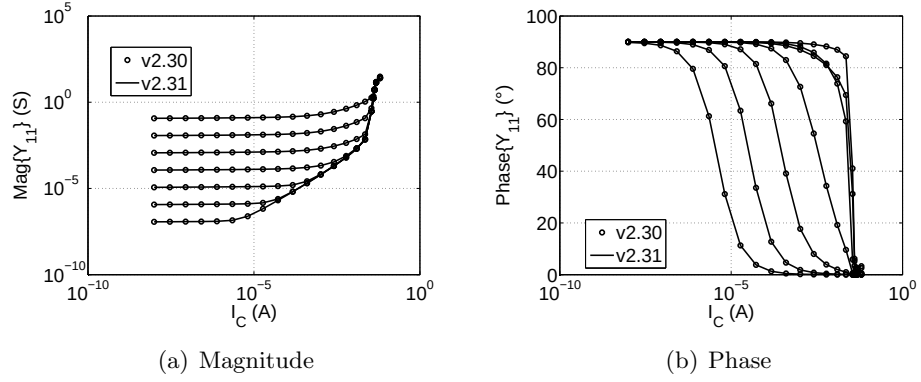


Figure 8.9: Magnitude and phase of Y_{11} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

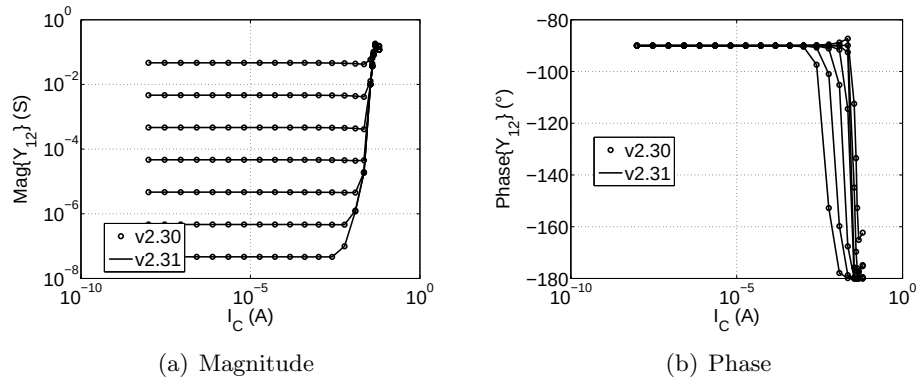


Figure 8.10: Magnitude and phase of Y_{12} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

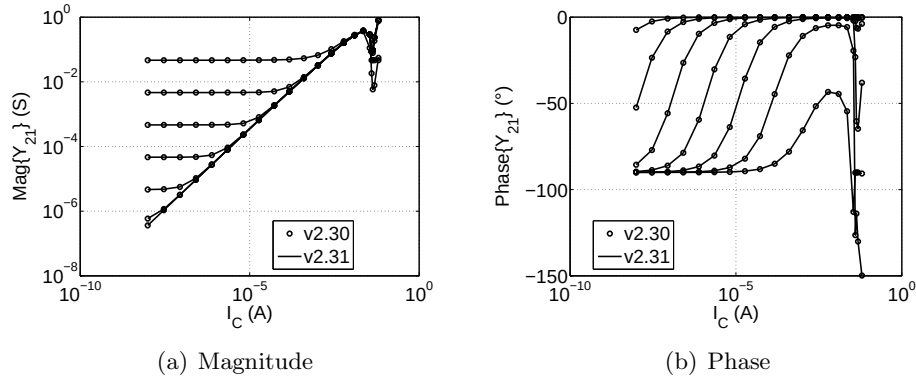


Figure 8.11: Magnitude and phase of Y_{21} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

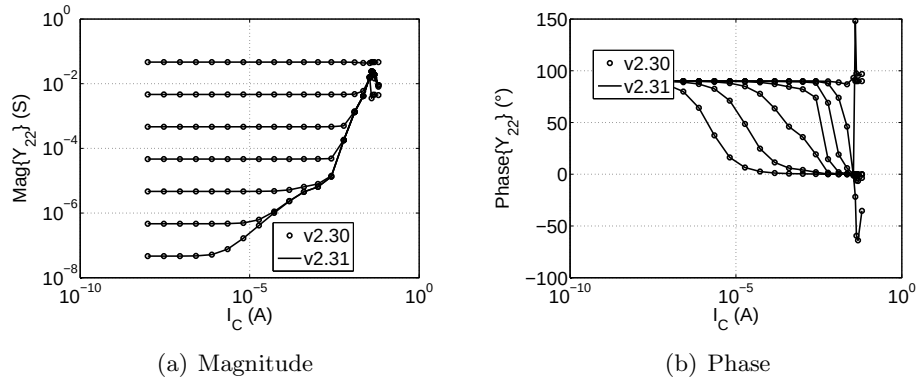


Figure 8.12: Magnitude and phase of Y_{22} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

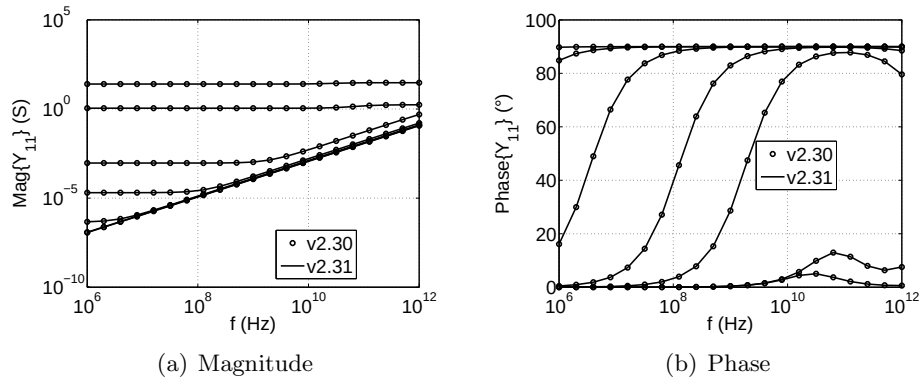


Figure 8.13: Magnitude and phase of Y_{11} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

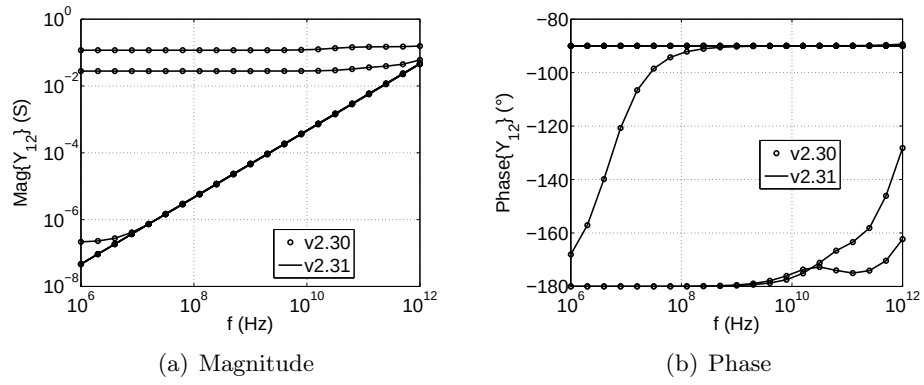


Figure 8.14: Magnitude and phase of Y_{12} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

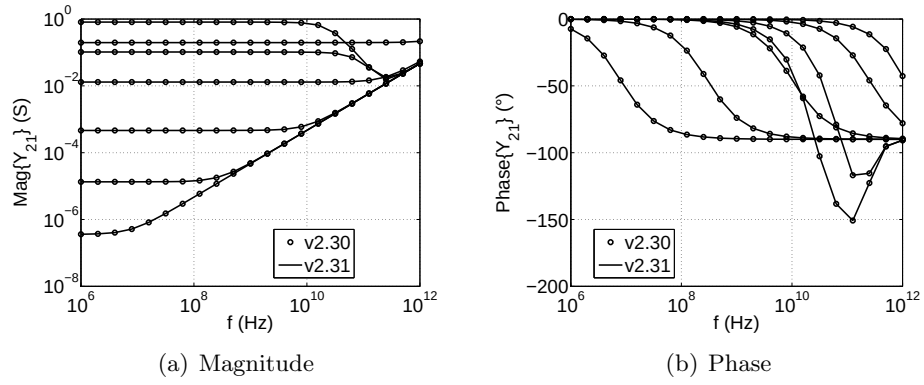


Figure 8.15: Magnitude and phase of Y_{21} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

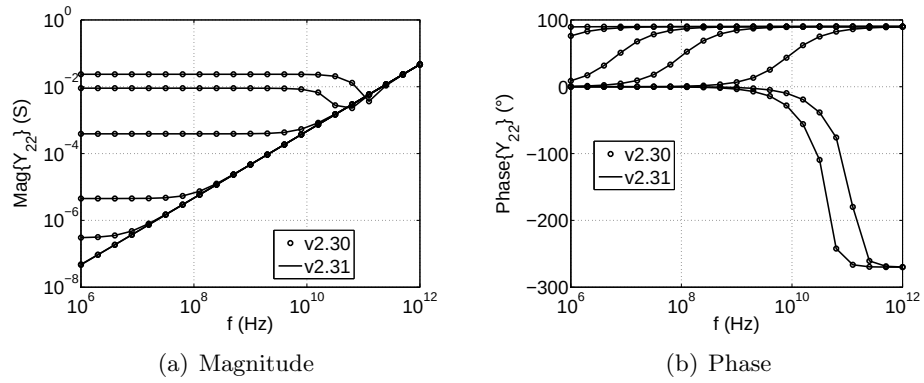


Figure 8.16: Magnitude and phase of Y_{22} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

9 Internal transistor including lateral NQS-effect

Since for this model card only small signal parameters are effected, no DC curves are shown here. The modeling of the lateral NQS effect in v2.24 was different from that in v2.23 and v2.30 (which have used the same model. In v2.31, the model v2.30 was simplified in order to reduce code size and simulation time.

Resulting from this, deviations between v2.31 and v2.24 and between v2.31 and v2.30 (and v2.23) exists. However latter deviations only appear for operating points above peak f_T .

9.1 Model cards

9.1.1 Version 2.31, compatible to 2.24

```
c10=2.0175e-032 qp0=2.155e-016 ich=0 hfe=1.8331
hfc=0.05 hjei=0.034883 hjci=0.0026778 ibeis=2.82e-020
mbei=1.012 ireis=2.7167e-015 mrei=2.263 ibeps=0 mbep=1
ireps=0 mrep=2 mcf=1 tbhrec=1e-012 ibcis=1.165e-019
mbci=1.066 ibcx=0 mbcx=1 ibets=1e-014 abet=40 tunode=1
favl=240.3 qavl=1.1756e-013 alfav=-0.009966 alqav=-0.0009569
rbi0=25 rbx=0 fgeo=0.6557 fdqr0=13 fcrbi=0.6 fqi=1 re=0
rcx=0 itss=0 msf=1 iscs=0 msc=1 tsf=0 rsu=0 csu=0
cjei0=9.3264e-015 vdei=0.87043 ze=0.20065 ajei=2.1953 cjep0=1e-020
vdep=0.9 zep=0.5 ajep=2.5 cjci0=7.4192e-015 vdc=0.73351
zci=0.36198 vptci=3.2461 cjc0=1e-020 vdcx=0.7 zcx=0.4
vptcx=100 fbcpar=0 fbepar=1 cjs0=0 vds=0.6 zs=0.5 vpts=100
t0=2.2784e-013 dt0h=1.0591e-013 tbvl=1.5456e-014
tef0=4.4727e-013 gtfe=1.4744 thcs=1e-011 ahc=0.06 fthc=0.5
rci0=19.44 vlim=1.429 vces=0.001 vpt=18 tr=0 cbepar=0
cbcp=0 alqf=0.16667 alit=0.33333 flnqs=0 kf=0 af=2
cfbe=-1 latb=0 latl=0 vgb=0.9 alt0=0.0025354 kt0=1e-005
zetaci=0.5621 alvs=0.00217 alces=-0.00584 zetarbi=0 zetarbx=0
zetarcx=0 zetare=0 zetacx=1 vge=1.17 vgc=1.17 vgs=1.17
flvg=-0.00010238 f2vg=0.00043215 zetact=5.3125 zetabet=1.3855
alb=0 flsh=0 rth=0 cth=0 flcomp=2.2 tnom=27 dt=0
zetarth=0 type=1 flcono=0
```

9.1.2 Version 2.31, compatible to 2.30

```
c10=2.0175e-032 qp0=2.155e-016 ich=0 hfe=1.8331
hfc=0.05 hjei=0.034883 hjci=0.0026778 ibeis=2.82e-020
mbei=1.012 ireis=2.7167e-015 mrei=2.263 ibeps=0 mbep=1
ireps=0 mrep=2 mcf=1 tbhrec=1e-012 ibcis=1.165e-019
mbci=1.066 ibcx=0 mbcx=1 ibets=1e-014 abet=40 tunode=1
fav1=240.3 qavl=1.1756e-013 alfav=-0.009966 alqav=-0.0009569
rbi0=25 rbx=0 fgeo=0.6557 fdqr0=13 fcrbi=0.6 fqi=1 re=0
rcx=0 itss=0 msf=1 iscs=0 msc=1 tsf=0 rsu=0 csu=0
cjei0=9.3264e-015 vdei=0.87043 zei=0.20065 ajei=2.1953 cjep0=1e-020
vdep=0.9 zep=0.5 ajep=2.5 cjci0=7.4192e-015 vdci=0.73351
zci=0.36198 vptci=3.2461 cjcx0=1e-020 vdcx=0.7 zcx=0.4
vptcx=100 fbcpar=0 fbepar=1 cjs0=0 vds=0.6 zs=0.5 vpts=100
t0=2.2784e-013 dt0h=1.0591e-013 tbvl=1.5456e-014
tef0=4.4727e-013 gtfe=1.4744 thcs=1e-011 ahc=0.06 fthc=0.5
rci0=19.44 vlim=1.429 vces=0.001 vpt=18 tr=0 cbepar=0
cbcpar=0 alqf=0.16667 alit=0.33333 flnqs=0 kf=0 af=2
cfbe=-1 latb=0 latl=0 vgb=0.9 alt0=0.0025354 kt0=1e-005
zetaci=0.5621 alvs=0.00217 alces=-0.00584 zetarbi=0 zetarbx=0
zetarcx=0 zetare=0 zetacx=1 vge=1.17 vgc=1.17 vgs=1.17
f1vg=-0.00010238 f2vg=0.00043215 zetact=5.3125 zetabet=1.3855
alb=0 flsh=0 rth=0 cth=0 flcomp=2.3 tnom=27 dt=0
zetarth=0 type=1 flcono=0 hf0=0.24679 ahjei=5.912 rhjei=2
vcbar=0.04 icbar=0.003 acbar=1.5 delck=1.8 dvge=-0.1103
zetahjei=-0.78133 zetavgbe=0.7 alrth=0
```

9.2 Simulation results

9.2.1 Comparison between version 2.31 and 2.24

Small signal results

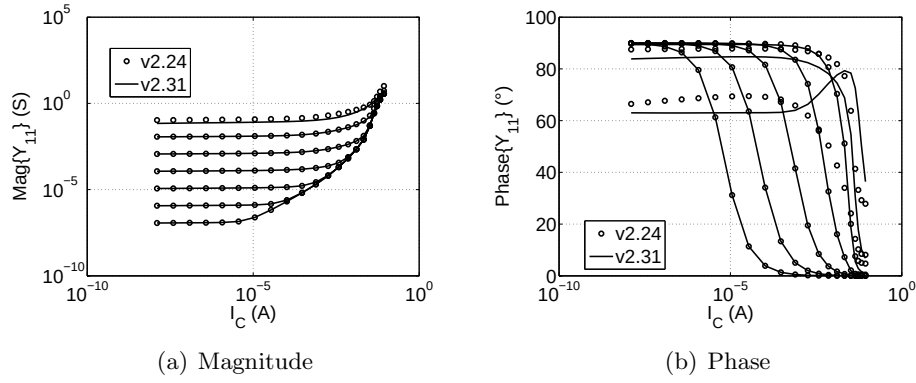


Figure 9.1: Magnitude and phase of Y_{11} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

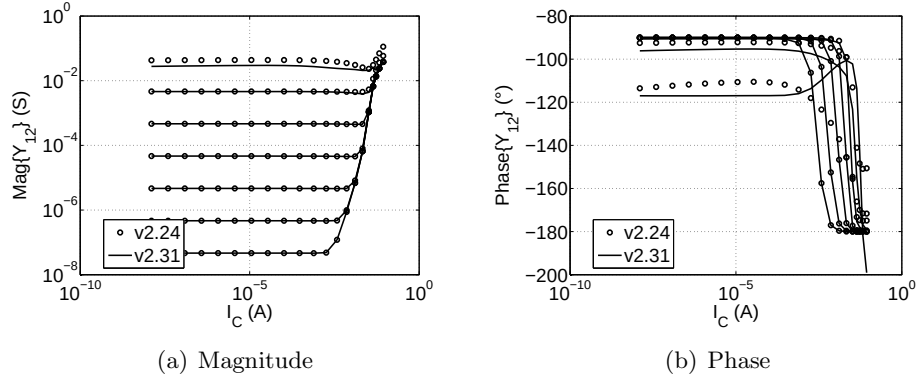


Figure 9.2: Magnitude and phase of Y_{12} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

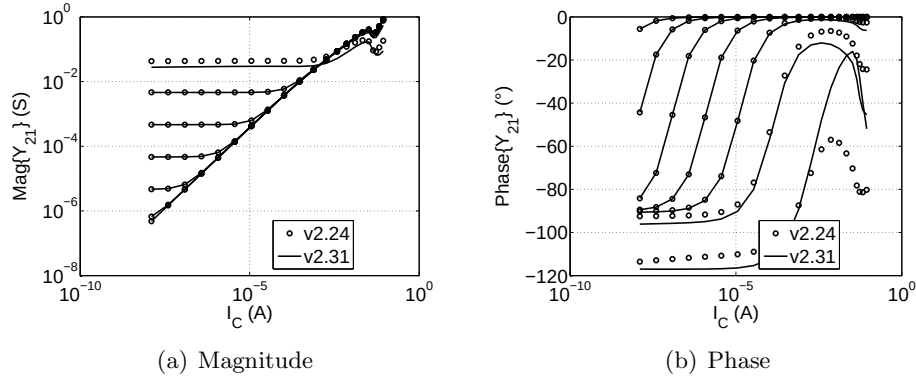


Figure 9.3: Magnitude and phase of Y_{21} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

9 Internal transistor including lateral NQS-effect

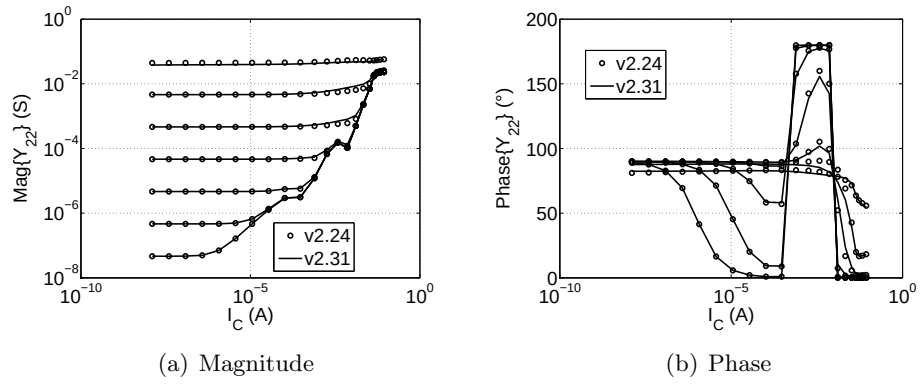


Figure 9.4: Magnitude and phase of Y_{22} versus collector current for $f=1\text{ MHz} \dots 1\text{ THz}$ at $V_{BC} = 0.0V$ and room temperature

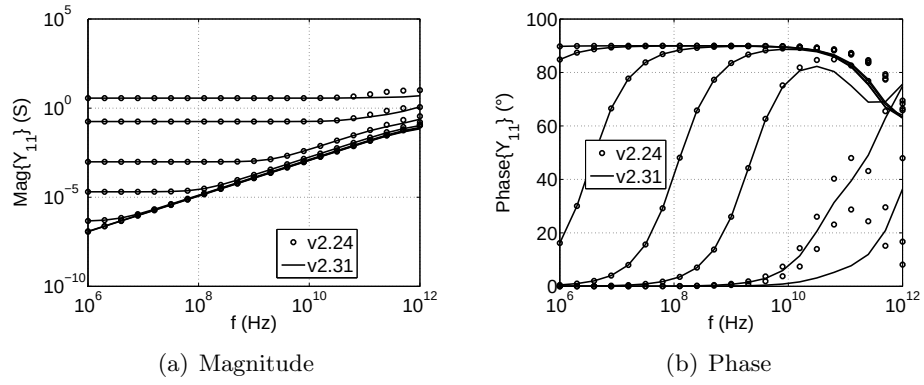


Figure 9.5: Magnitude and phase of Y_{11} versus frequency for $V_{BE} = 0.5 \dots 1.1V$ at $V_{BC} = 0.0V$ and room temperature

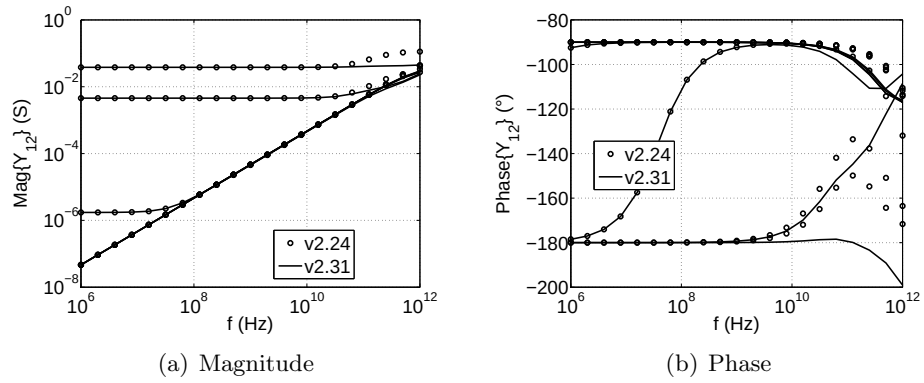


Figure 9.6: Magnitude and phase of Y_{12} versus frequency for $V_{BE} = 0.5 \dots 1.1V$ at $V_{BC} = 0.0V$ and room temperature

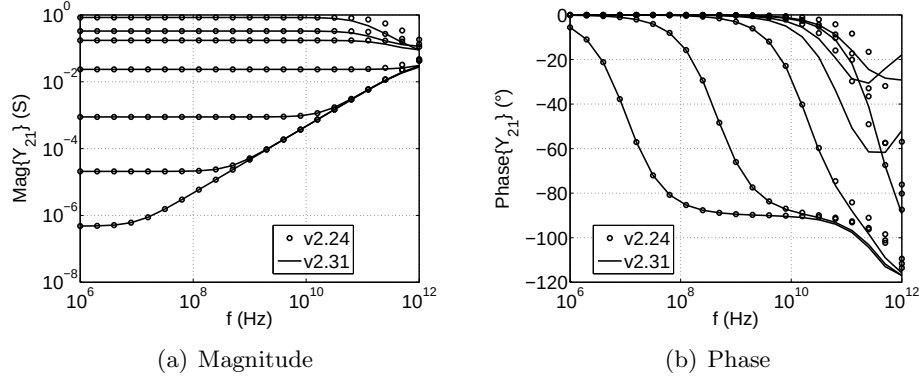


Figure 9.7: Magnitude and phase of Y_{21} versus frequency for $V_{BE} = 0.5 \dots 1.1V$ at $V_{BC} = 0.0V$ and room temperature

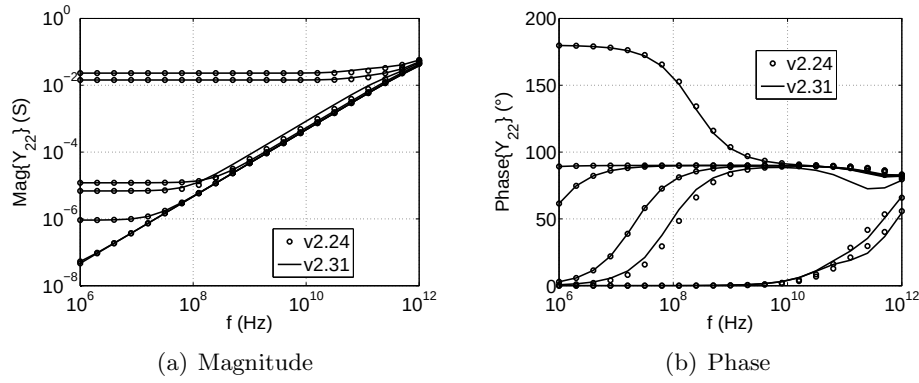


Figure 9.8: Magnitude and phase of Y_{22} versus frequency for $V_{BE} = 0.5 \dots 1.1V$ at $V_{BC} = 0.0V$ and room temperature

9.2.2 Comparison between version 2.31 and 2.30

Small signal results

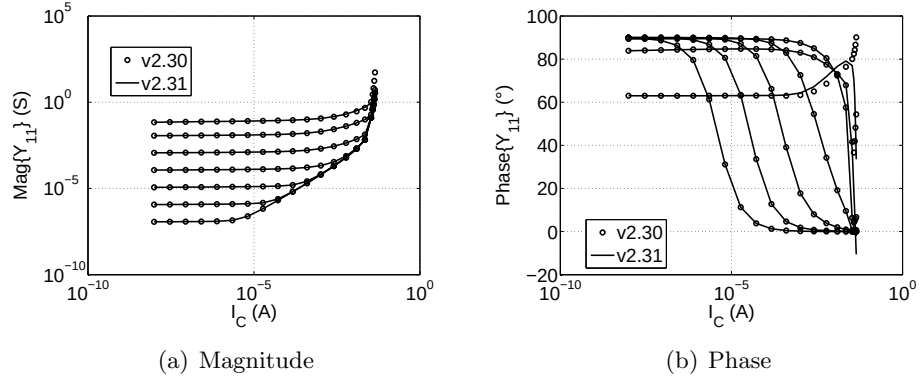


Figure 9.9: Magnitude and phase of Y_{11} versus collector current for $f=1\text{ MHz} \dots 1\text{ THz}$ at $V_{BC} = 0.0V$ and room temperature

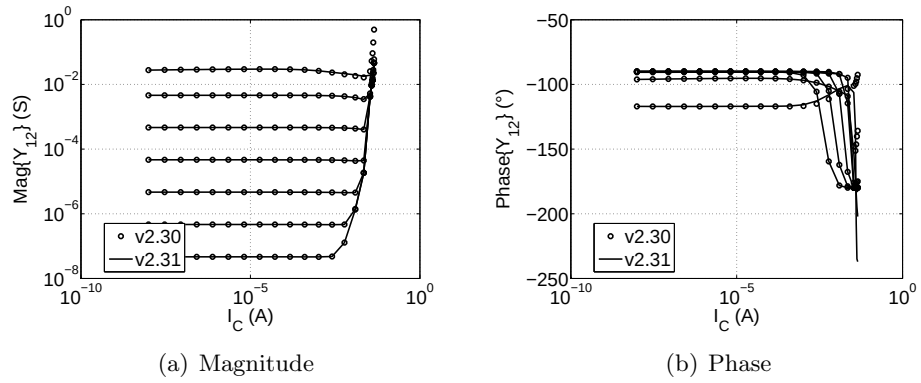


Figure 9.10: Magnitude and phase of Y_{12} versus collector current for $f=1\text{ MHz} \dots 1\text{ THz}$ at $V_{BC} = 0.0V$ and room temperature

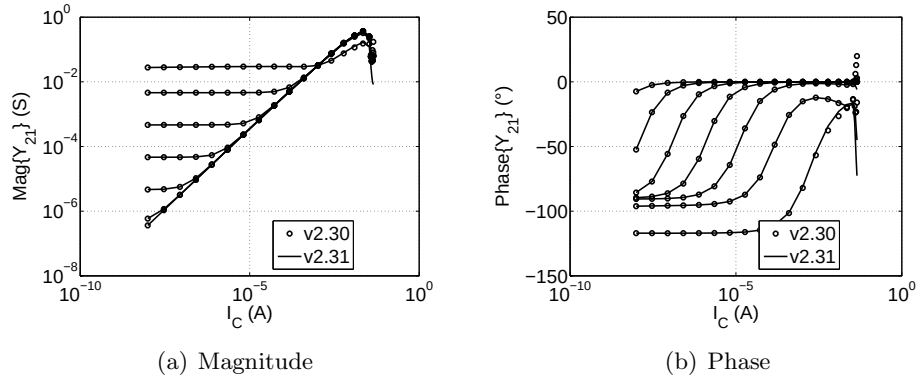


Figure 9.11: Magnitude and phase of Y_{21} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

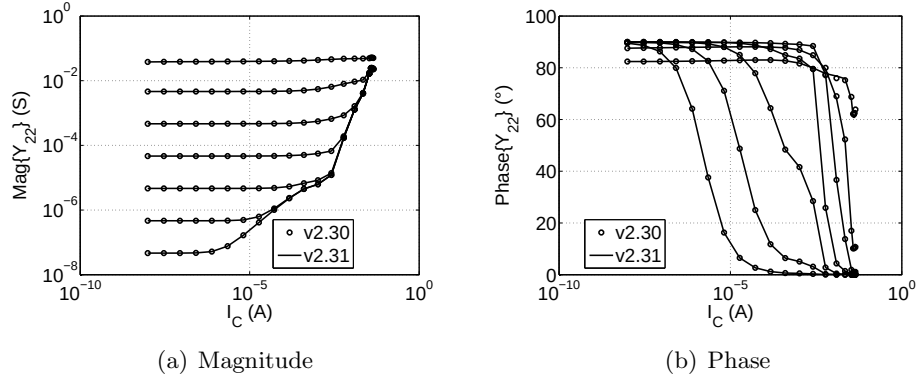


Figure 9.12: Magnitude and phase of Y_{22} versus collector current for $f=1$ MHz...1 THz at $V_{BC} = 0.0V$ and room temperature

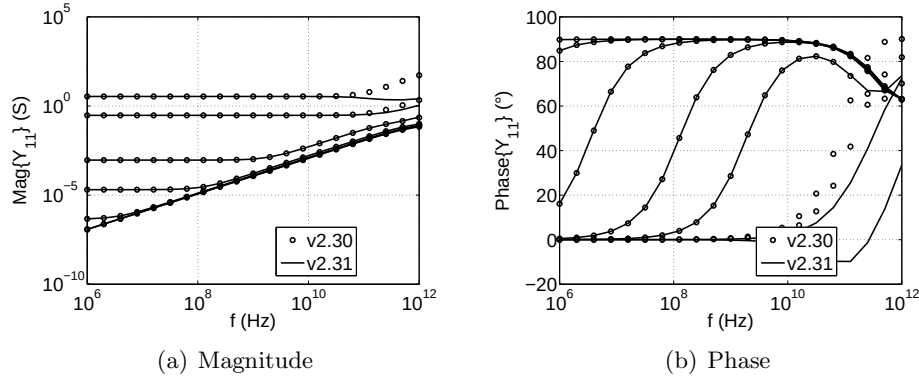


Figure 9.13: Magnitude and phase of Y_{11} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

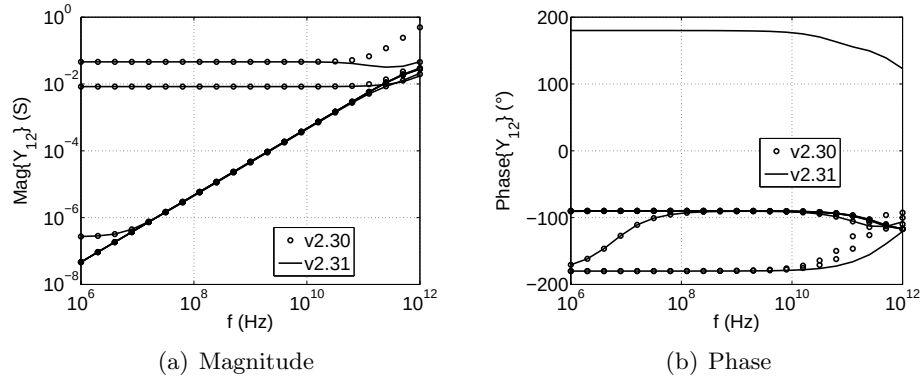


Figure 9.14: Magnitude and phase of Y_{12} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

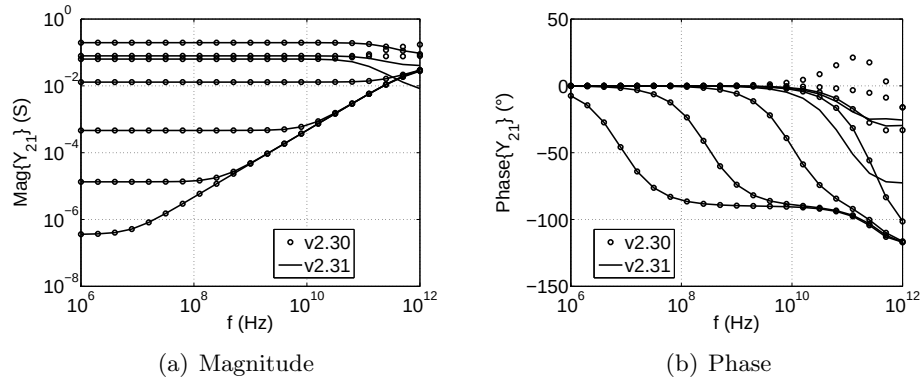


Figure 9.15: Magnitude and phase of Y_{21} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

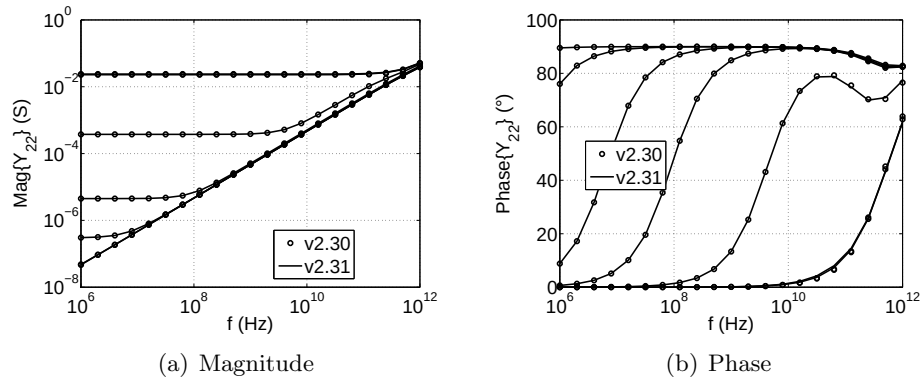


Figure 9.16: Magnitude and phase of Y_{22} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature

10 1D Transistor using m_{cf}

For this model card, no small signal results are shown.

10.1 Model cards

10.1.1 Version 2.31, compatible to 2.24

```
c10=2.0175e-032 qp0=2.155e-016 ich=0 hfe=1.8331
hfc=0.05 hjei=0.034883 hjci=0.0026778 ibeis=2.82e-020
mbei=1.012 ireis=2.7167e-015 mrei=2.263 ibeps=0 mbep=1
ireps=0 mrep=2 mcf=1.1 tbhrec=1e-012 ibcis=1.165e-019
mbci=1.066 ibcx=0 mbcx=1 ibets=0 abet=40 tunode=1
fav1=240.3 qavl=1.1756e-013 alfav=-0.009966 alqav=-0.0009569
rbi0=0 rbx=0 fgeo=0.6557 fdqr0=0 fcrbi=0 fqi=1 re=0
rcx=0 itss=0 msf=1 iscs=0 msc=1 tsf=0 rsu=0 csu=0
cjei0=9.3264e-015 vdei=0.87043 zei=0.20065 ajei=2.1953 cjep0=1e-020
vdep=0.9 zep=0.5 ajep=2.5 cjci0=7.4192e-015 vdc1=0.73351
zci=0.36198 vptci=3.2461 cjc0=1e-020 vdcx=0.7 zcx=0.4
vptcx=100 fbcpar=0 fbepar=1 cjs0=0 vds=0.6 zs=0.5 vpts=100
t0=2.2784e-013 dt0h=1.0591e-013 tbvl=1.5456e-014
tef0=4.4727e-013 gtfe=1.4744 thcs=1e-011 ahc=0.06 fthc=0.5
rci0=19.44 vlim=1.429 vces=0.001 vpt=18 tr=0 cbepar=0
cbcpar=0 alqf=0.16667 alit=0.33333 flnqs=0 kf=0 af=2
cfbe=-1 latb=0 latl=0 vgb=0.9 alt0=0.0025354 kt0=1e-005
zetaci=0.5621 alvs=0.00217 alces=-0.00584 zetarbi=0 zetarbx=0
zetarcx=0 zetare=0 zetacx=1 vge=1.17 vgc=1.17 vgs=1.17
f1vg=-0.00010238 f2vg=0.00043215 zetact=5.3125 zetabet=1.3855
alb=0 flsh=0 rth=0 cth=0 flcomp=2.2 tnom=27 dt=0
zetarth=0 type=1 flcono=0
```

10.1.2 Version 2.31, compatible to 2.30

```
c10=2.0175e-032 qp0=2.155e-016 ich=0 hfe=1.8331
hfc=0.05 hjei=0.034883 hjci=0.0026778 ibeis=2.82e-020
mbei=1.012 ireis=2.7167e-015 mrei=2.263 ibeps=0 mbep=1
ireps=0 mrep=2 mcf=1.1 tbhrec=1e-012 ibcis=1.165e-019
mbci=1.066 ibcx=0 mbcx=1 ibets=0 abet=40 tunode=1
fav1=240.3 qavl=1.1756e-013 alfav=-0.009966 alqav=-0.0009569
```

```

rbi0=0 rbx=0 fgeo=0.6557 fdqr0=0 fcrbi=0 fqi=1 re=0
rcx=0 itss=0 msf=1 iscs=0 msc=1 tsf=0 rsu=0 csu=0
cjei0=9.3264e-015 vdei=0.87043 zei=0.20065 ajei=2.1953 cjep0=1e-020
vdep=0.9 zep=0.5 ajep=2.5 cjc0=7.4192e-015 vdc0=0.73351
zci=0.36198 vptci=3.2461 cjc0=1e-020 vdcx=0.7 zcx=0.4
vptcx=100 fbcpar=0 fbepar=1 cjs0=0 vds=0.6 zs=0.5 vpts=100
t0=2.2784e-013 dt0h=1.0591e-013 tbvl=1.5456e-014
tef0=4.4727e-013 gtfe=1.4744 thcs=1e-011 ahc=0.06 fthc=0.5
rci0=19.44 vlim=1.429 vces=0.001 vpt=18 tr=0 cbepar=0
cbcp=0 alqf=0.16667 alit=0.33333 flnqs=0 kf=0 af=2
cfbe=-1 latb=0 latl=0 vgb=0.9 alt0=0.0025354 kt0=1e-005
zetaci=0.5621 alvs=0.00217 alces=-0.00584 zetarbi=0 zetarbx=0
zetarcx=0 zetare=0 zetacx=1 vge=1.17 vgc=1.17 vgs=1.17
flvg=-0.00010238 f2vg=0.00043215 zetact=5.3125 zetabet=1.3855
alb=0 flsh=0 rth=0 cth=0 flcomp=2.3 tnom=27 dt=0
zetarth=0 type=1 flcono=0 hf0=0.24679 ahjei=5.912 rhjei=2
vcb=0.04 icb=0.003 acb=1.5 delck=1.8 dvgbe=-0.1103
zetahjei=-0.78133 zetavgbe=0.7 alrth=0

```

10.2 Simulation results

10.2.1 Comparison between version 2.31 and 2.24

Forward gummel

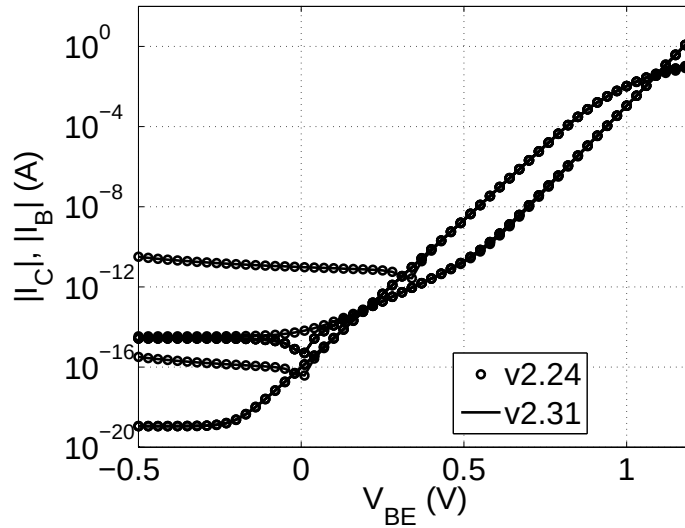


Figure 10.1: Forward gummel at room temperature for $V_{BC} = -0.9...0.3V$

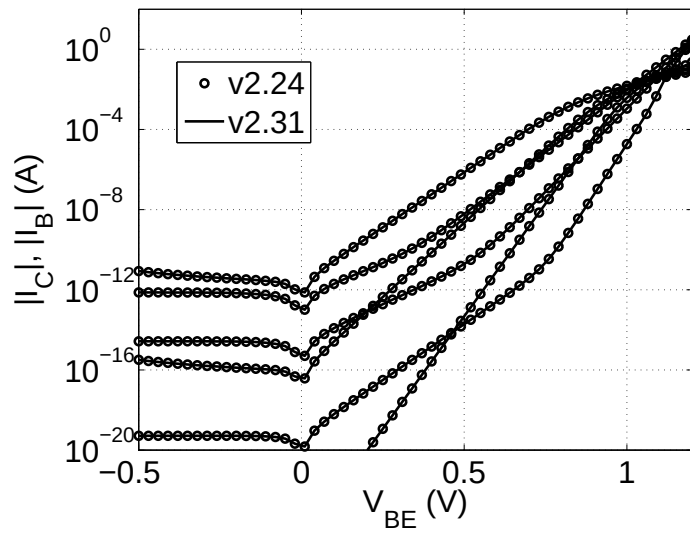


Figure 10.2: Forward gummel at $V_{BC} = 0.0V$ and $T = [200, 300, 400]K$

Reverse gummel

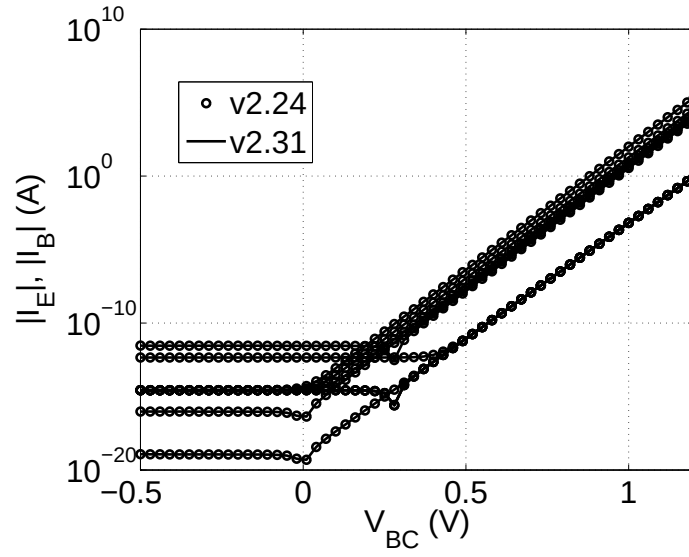


Figure 10.3: Reverse gummel at room temperature for $V_{BE} = -0.9...0.3V$

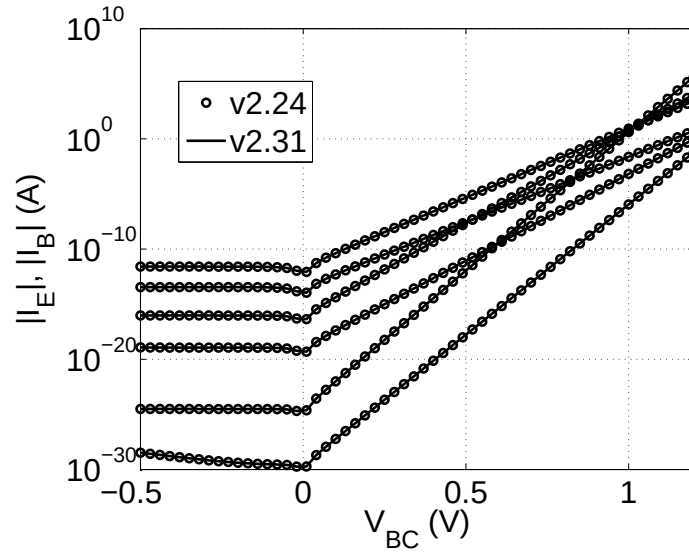
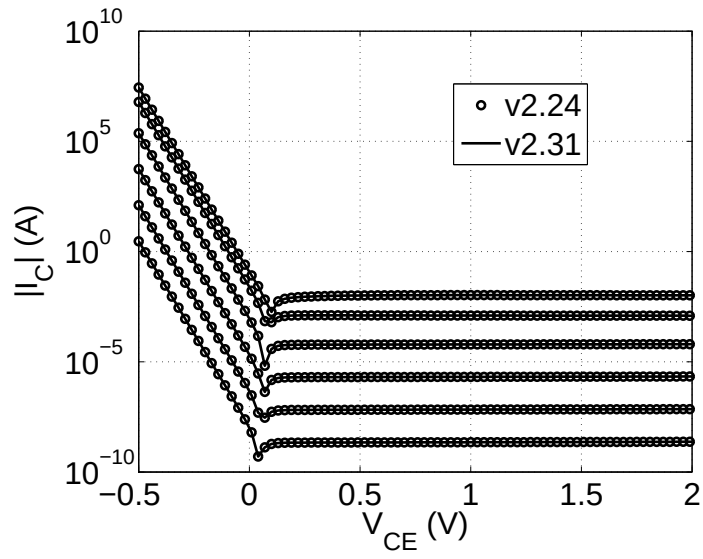
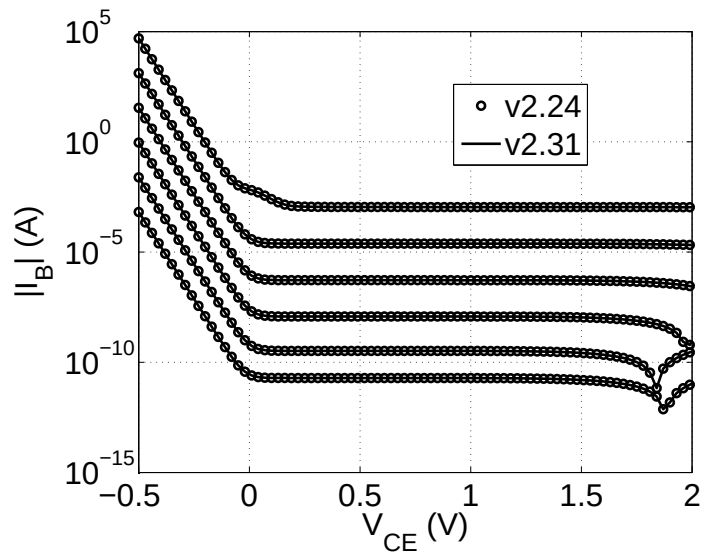


Figure 10.4: Reverse gummel at $V_{BE} = 0.0V$ and $T = [200, 300, 400]K$

Forward output, forced V_{BE} Figure 10.5: Forward output at forced V_{BE} Figure 10.6: Forward output at forced V_{BE}

Forward output, forced I_B

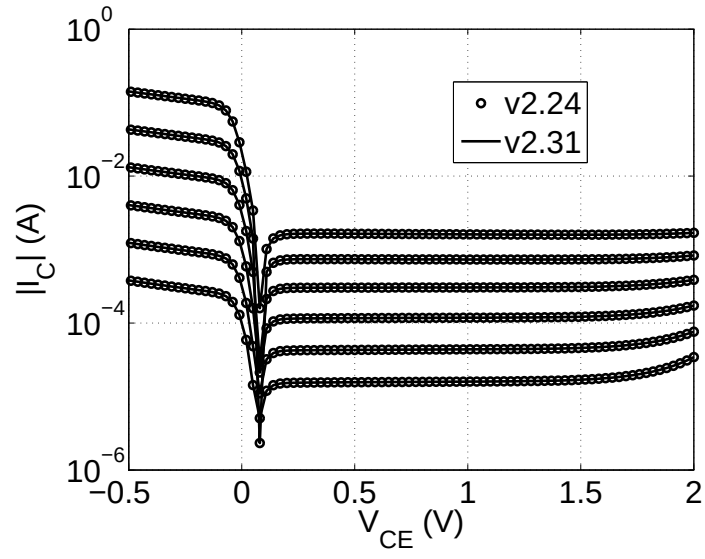


Figure 10.7: Forward output at forced I_B

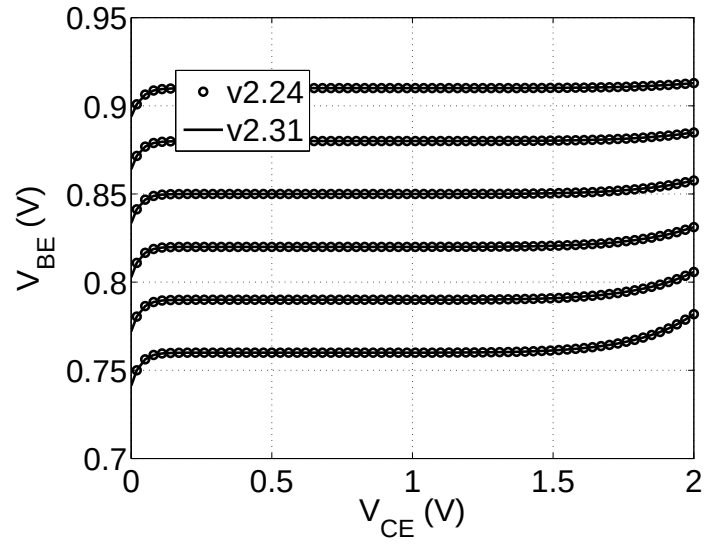
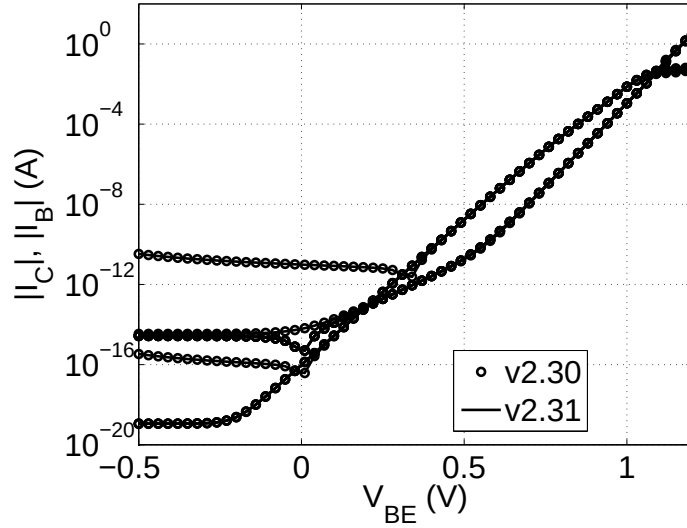
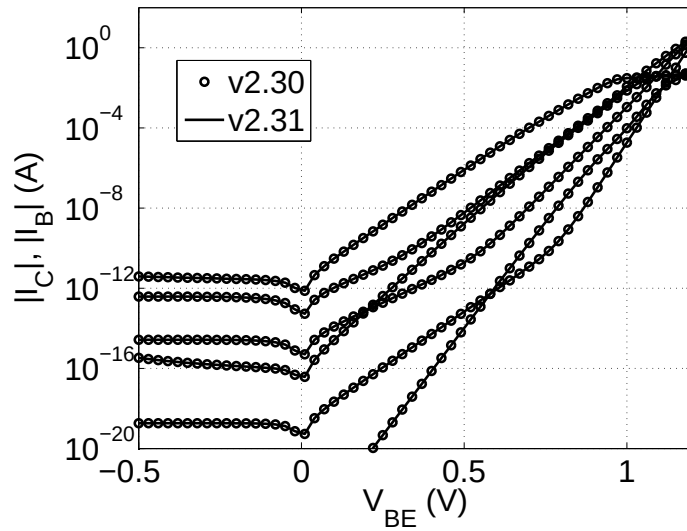


Figure 10.8: Forward output at forced I_B

10.2.2 Comparison between version 2.31 and 2.30

Forward gummel

Figure 10.9: Forward gummel at room temperature for $V_{BC} = -0.9...0.3V$ Figure 10.10: Forward gummel at $V_{BC} = 0.0V$ and $T = [200, 300, 400]K$

Reverse gummel

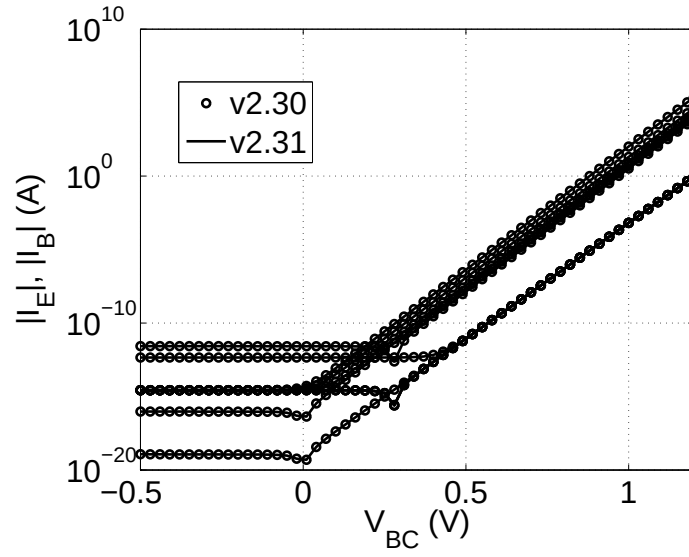


Figure 10.11: Reverse gummel at room temperature for $V_{BE} = -0.9...0.3V$

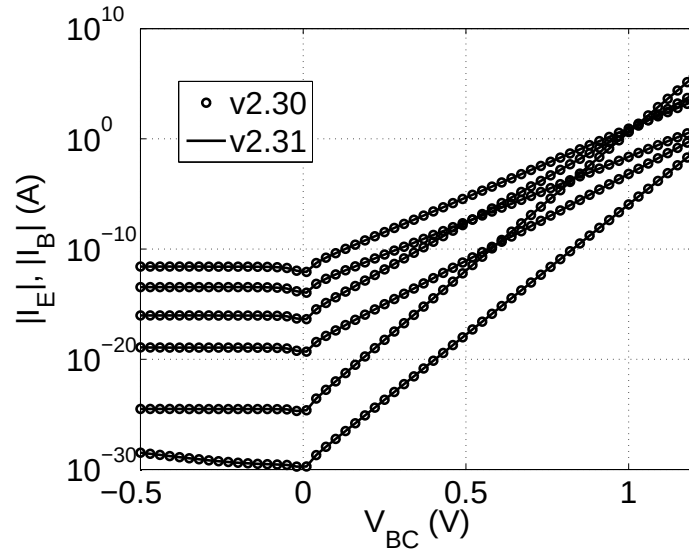
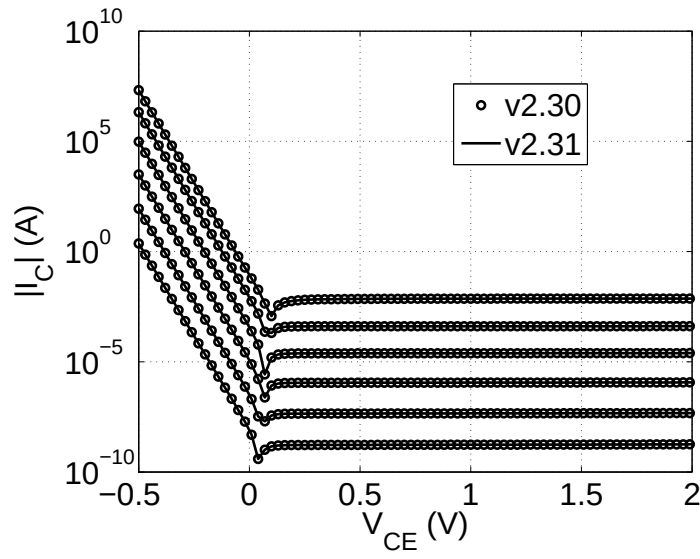
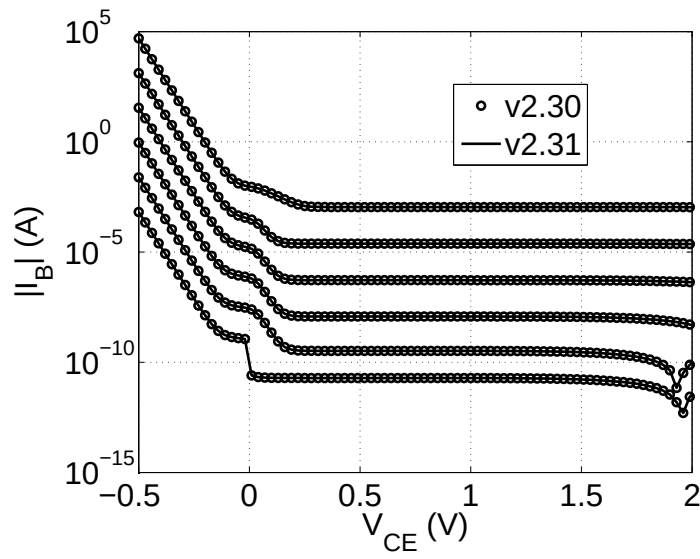


Figure 10.12: Reverse gummel at $V_{BE} = 0.0V$ and $T = [200, 300, 400]K$

Forward output, forced V_{BE} Figure 10.13: Forward output at forced V_{BE} Figure 10.14: Forward output at forced V_{BE}

Forward output, forced I_B

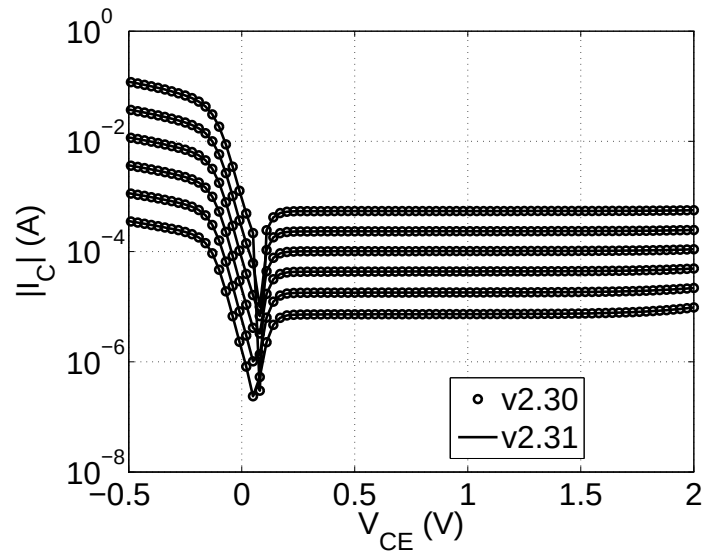


Figure 10.15: Forward output at forced I_B

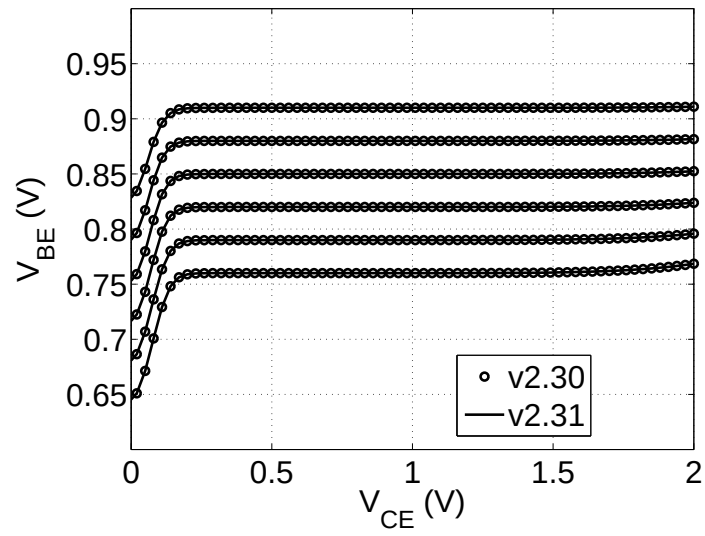


Figure 10.16: Forward output at forced I_B

11 Special characteristics

11.1 Vertical NQS effects

The chapter shows the application of the vertical NQS modeling in HICUM Level v2.31. The model cards corresponds the 1D transistor with vertical NQS parameters.

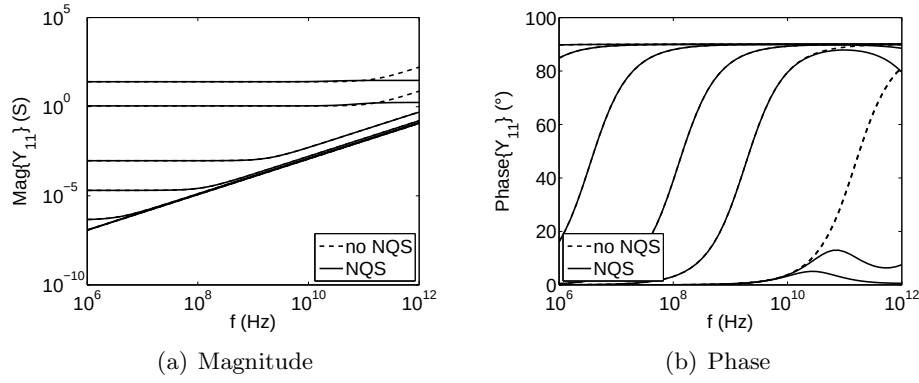


Figure 11.1: Magnitude and phase of Y_{11} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature including and excluding the modeling of vertical NQS-effects.

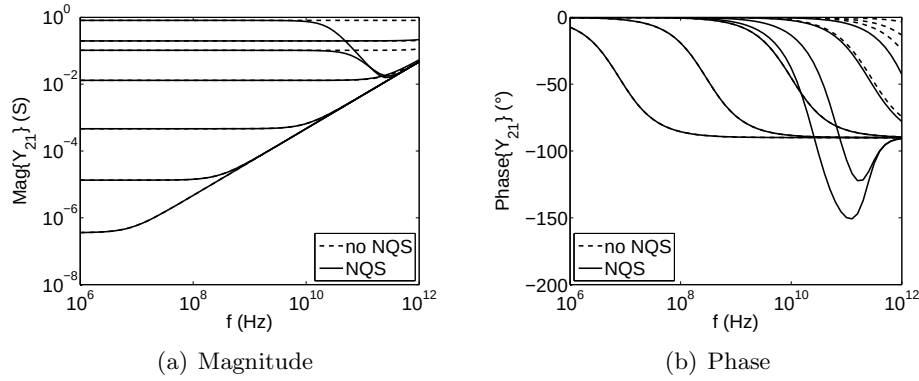


Figure 11.2: Magnitude and phase of Y_{21} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature including and excluding the modeling of vertical NQS-effects.

11.2 Lateral NQS effects

The chapter shows the application of the lateral NQS modeling in HICUM Level v2.31. The model cards corresponds the internal transistor with lateral NQS parameters.

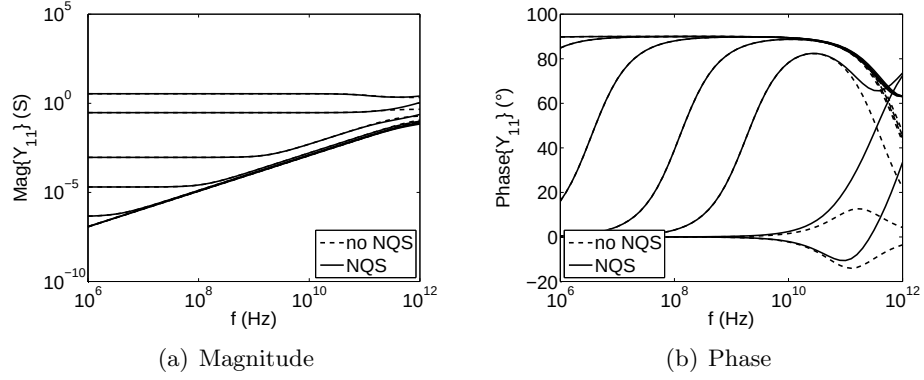


Figure 11.3: Magnitude and phase of Y_{11} versus frequency for $V_{BE} = 0.5 \dots 1.1V$ at $V_{BC} = 0.0V$ and room temperature including and excluding the modeling of lateral NQS-effects.

11.3 Self-heating

Starting with HICUM/L2 v2.30, a temperature dependent thermal resistance is modeled. Since the formulation in v2.31 slightly differs from that in v2.30, results are almost the same. When turning off the temperature dependence of the R_{th} , backward compatibility to the previous versions is maintained.

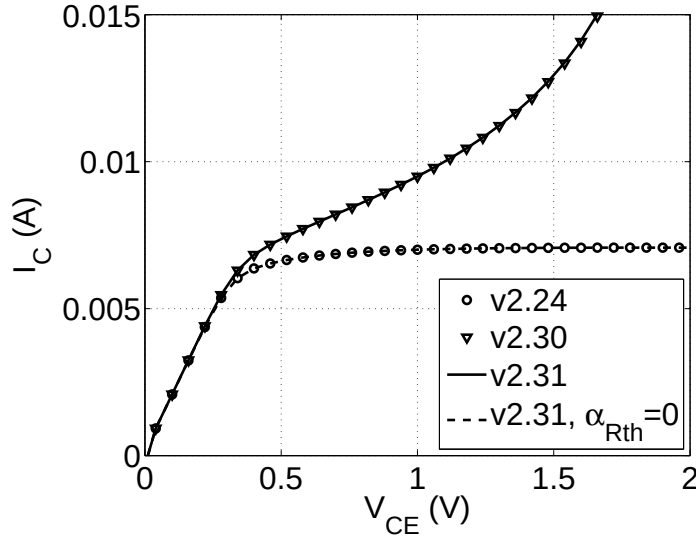


Figure 11.4: Forward output collector current at room temperature including and excluding the modeling of a temperature dependent thermal resistance.

11.4 Correlated noise modeling

In HICUM/L2 v2.31, correlated noise is modeled.

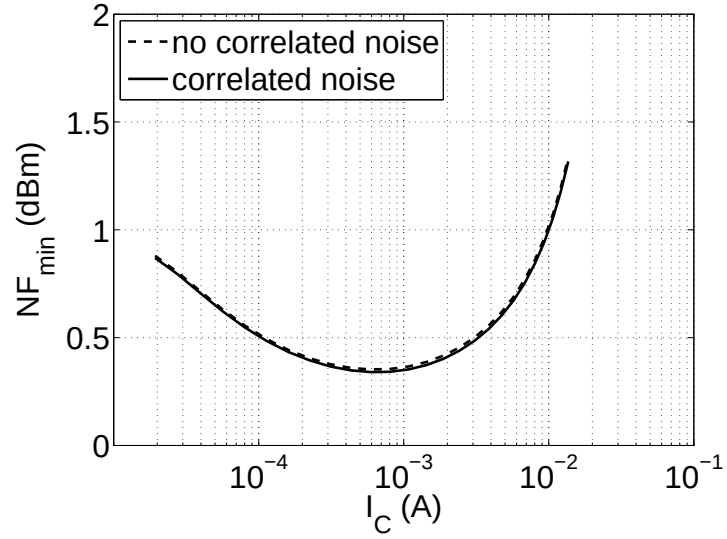


Figure 11.5: Minimum noise figure versus collector current at room temperature including and excluding the modeling of correlated noise.

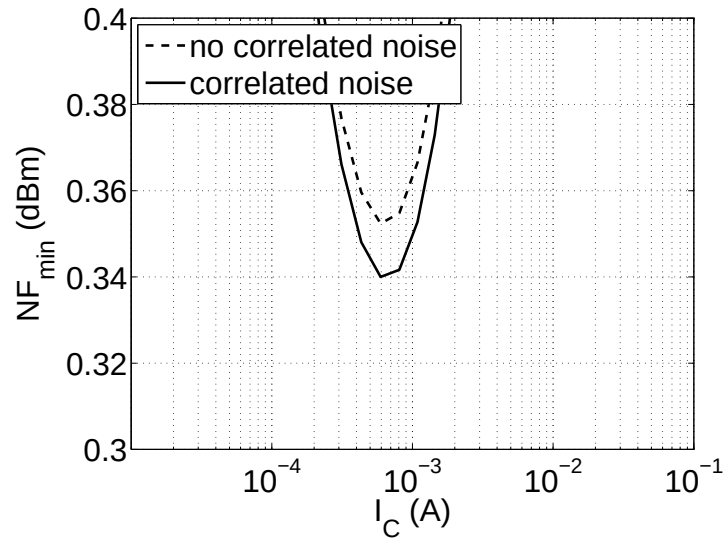


Figure 11.6: Minimum noise figure versus collector current at room temperature including and excluding the modeling of correlated noise.

11.5 PNP flag

HICUM/L2 v2.31 introduces a pnp-flag. In order to verify the correct implementation, the same model card for npn- and pnp-transistor were used except for the different value of *TYPE*. The same characteristics with opposite sign for each sweep variable were simulated. The used model card corresponds to the complete transistor including substrate transistor and substrate network, except for special characteristics.

11.5.1 Forward gummel

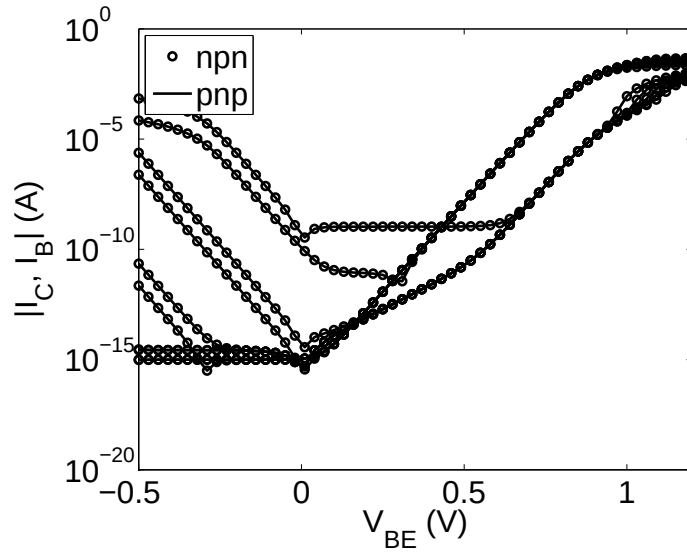


Figure 11.7: Forward transfer and bases current at room temperature for $V_{BC} = -0.9..0.3V$.

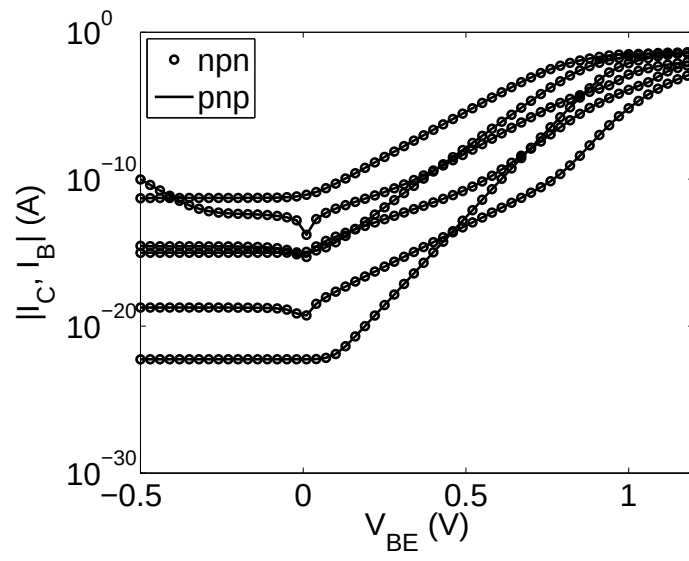


Figure 11.8: Forward transfer and bases current at $V_{BC} = 0V$ and $T=200..400K$.

11.5.2 Reverse gummel

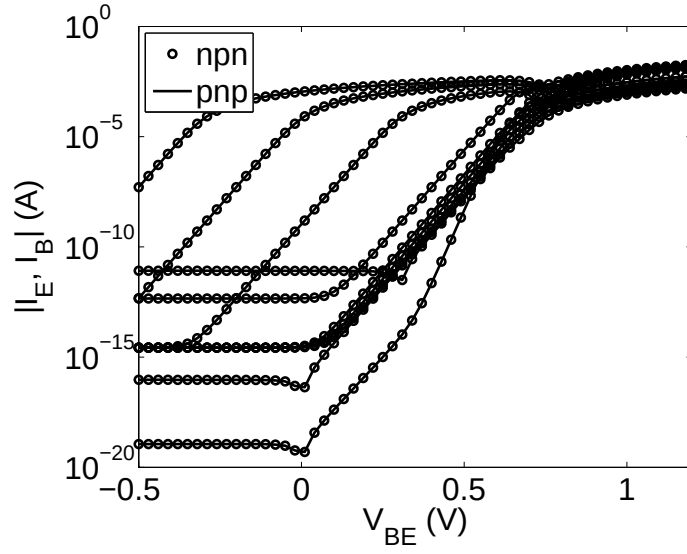


Figure 11.9: Reverse transfer and bases current at room temperature for $V_{BE} = -0.9..0.3V$.

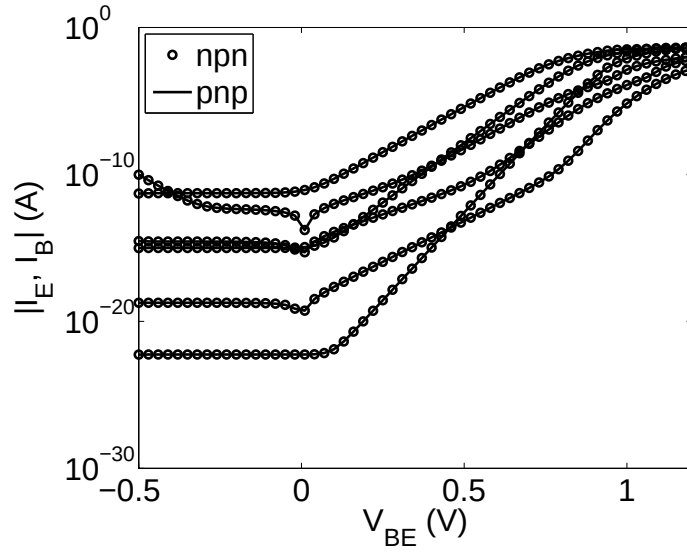


Figure 11.10: Reverse transfer and bases current at $V_{BE} = 0V$ and $T=200..400K$.

11.5.3 Forward output with forced V_{BE}

Here, all possible values for (*flsh*) were used for comparison.

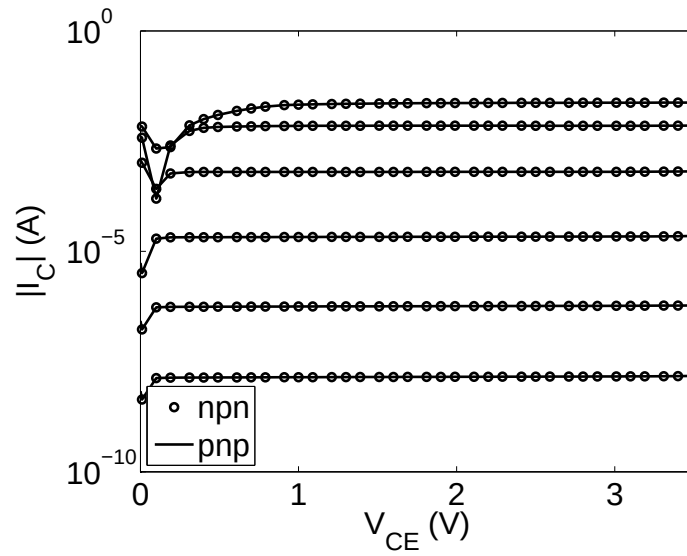


Figure 11.11: Forward output at forced V_{BE} with *flsh*=0

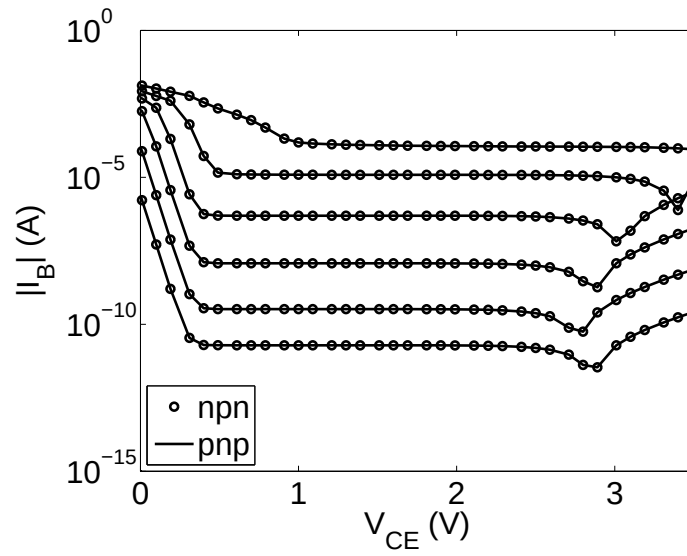


Figure 11.12: Forward output at forced V_{BE} with *flsh*=0

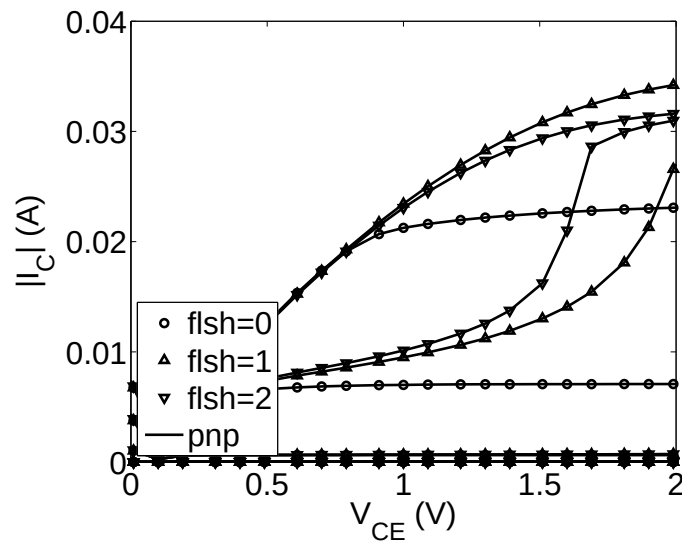


Figure 11.13: Forward output at forced V_{BE} with $flsh=[0,1,2]$

11.5.4 Forward output with forced I_B

Also here, all possible values for (*flsh*) were used for comparison.

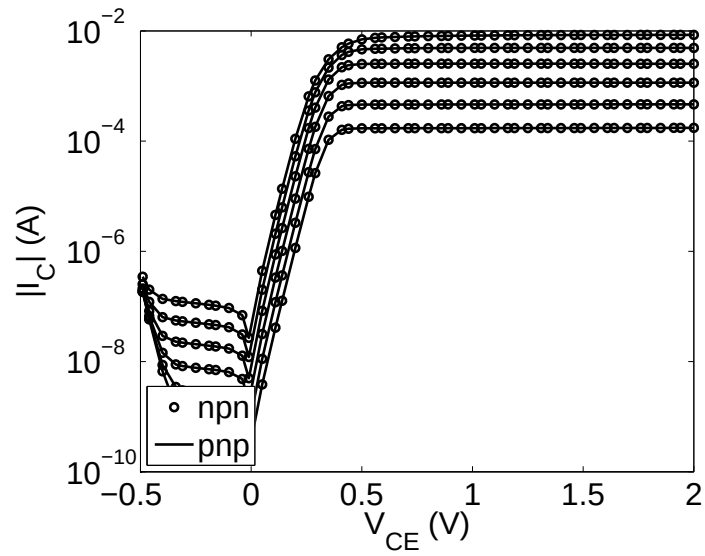


Figure 11.14: Forward output at forced V_{BE} with *flsh*=0

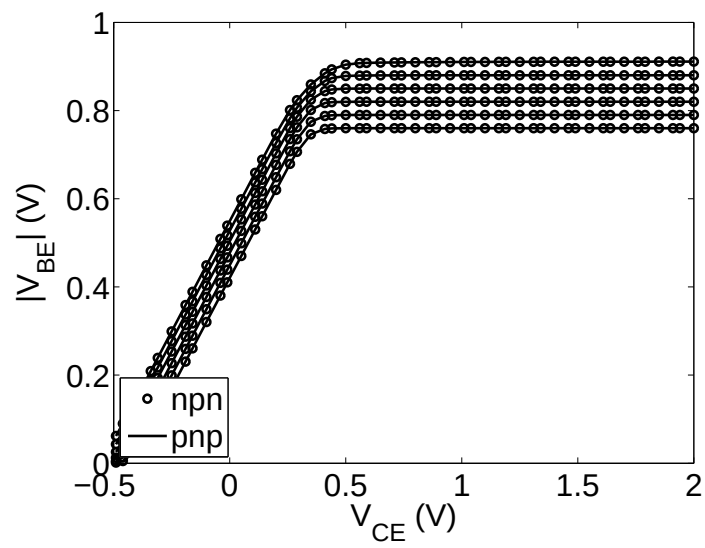
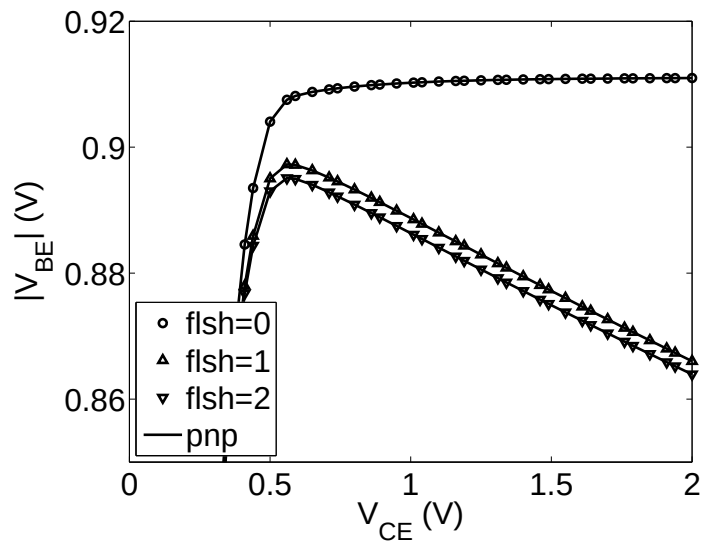


Figure 11.15: Forward output at forced V_{BE} with *flsh*=0

Figure 11.16: Forward output at forced V_{BE} with $flsh=[0,1,2]$

11.5.5 Small signal results

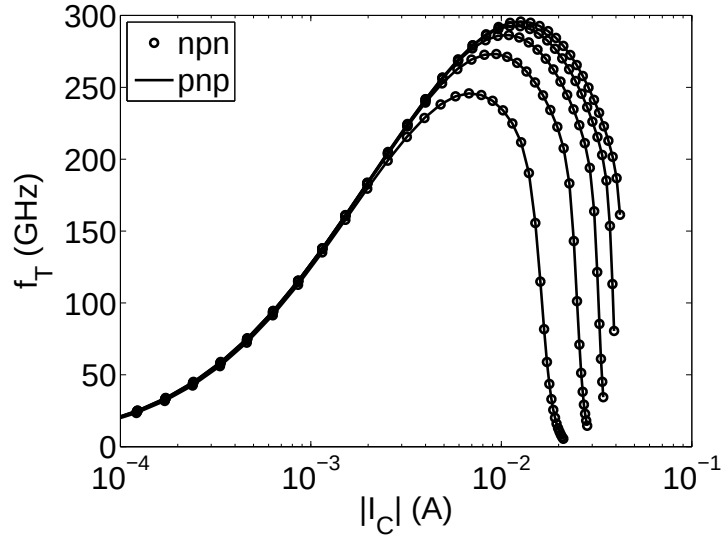


Figure 11.17: Transit frequency at room temperature for $V_{BC} = -0.9..0.3V$.

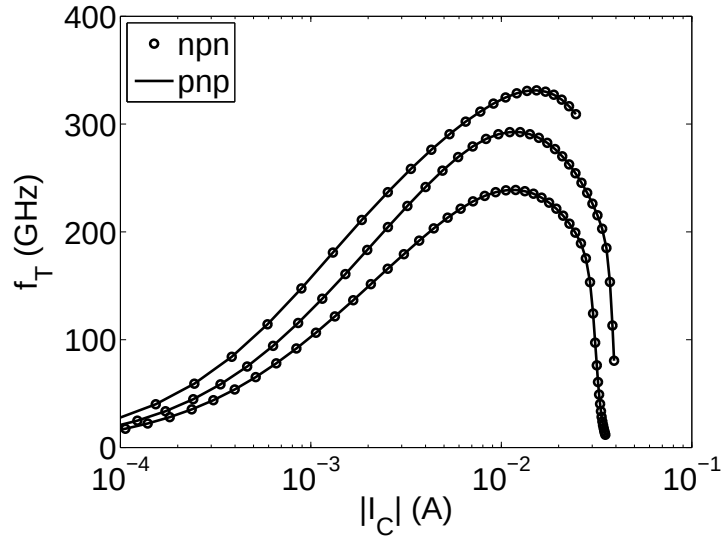


Figure 11.18: Transit frequency at $V_{BC} = 0V$ and $T=200..400K$.

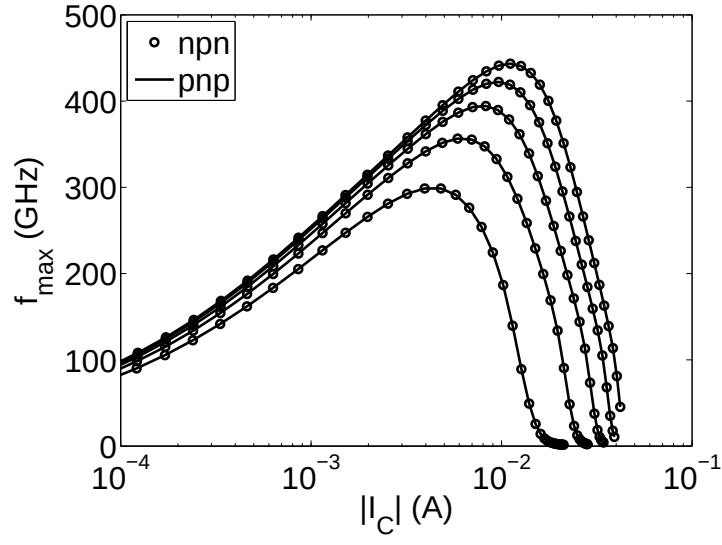


Figure 11.19: Maximum oscillation frequency at room temperature for $V_{BC} = -0.9..0.3V$.

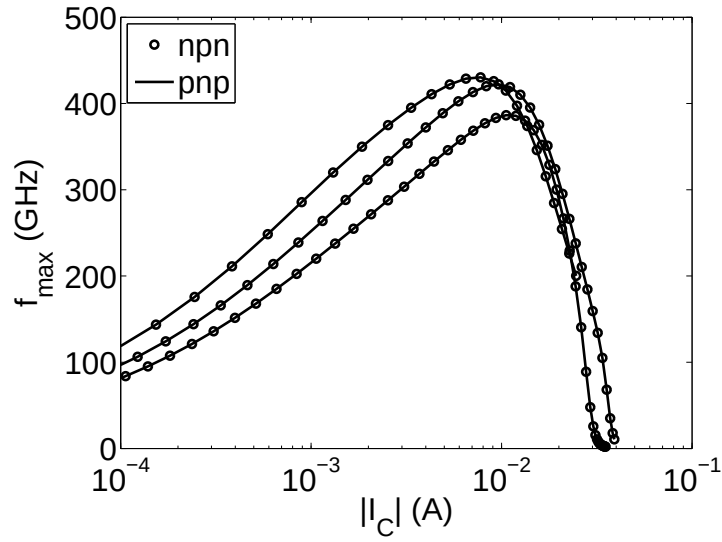


Figure 11.20: Maximum oscillation frequency at $V_{BC} = 0V$ and $T = 200..400K$.

11 Special characteristics

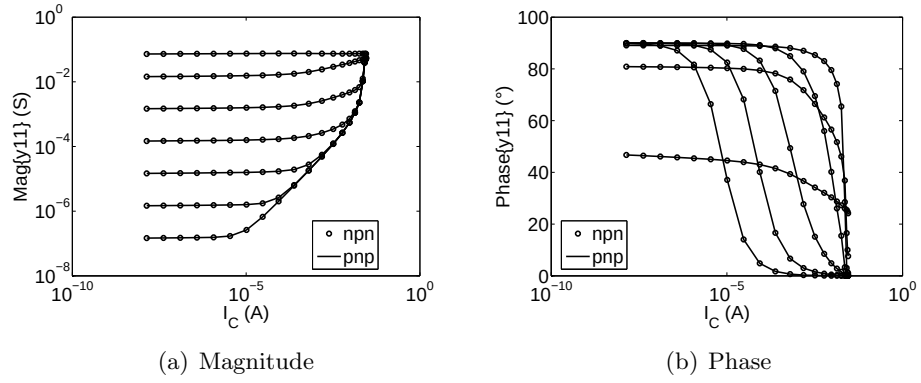


Figure 11.21: Magnitude and phase of Y_{11} versus collector current for $f=1\text{ MHz}\dots 1\text{ THz}$ at $V_{BC} = 0.0V$ and room temperature

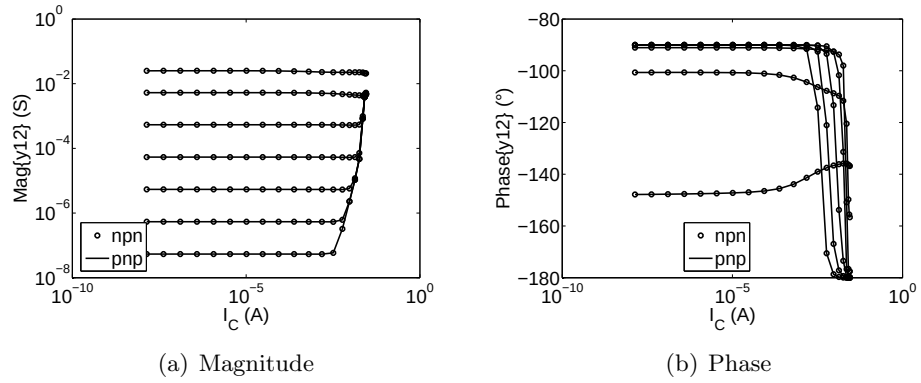


Figure 11.22: Magnitude and phase of Y_{12} versus collector current for $f=1\text{ MHz}\dots 1\text{ THz}$ at $V_{BC} = 0.0V$ and room temperature

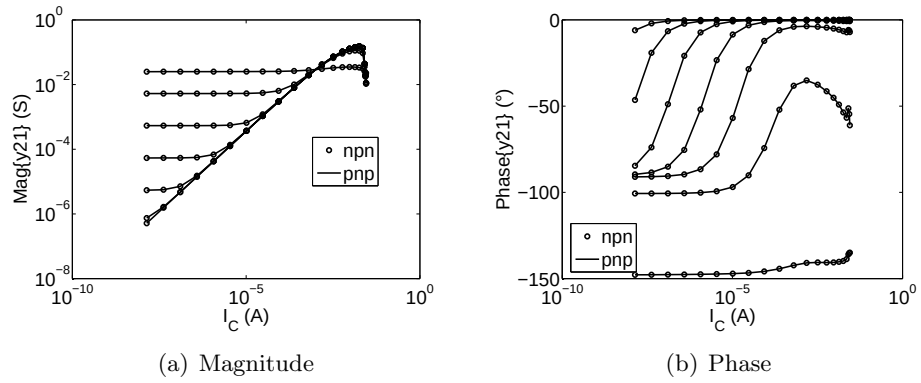


Figure 11.23: Magnitude and phase of Y_{21} versus collector current for $f=1\text{ MHz}\dots 1\text{ THz}$ at $V_{BC} = 0.0V$ and room temperature

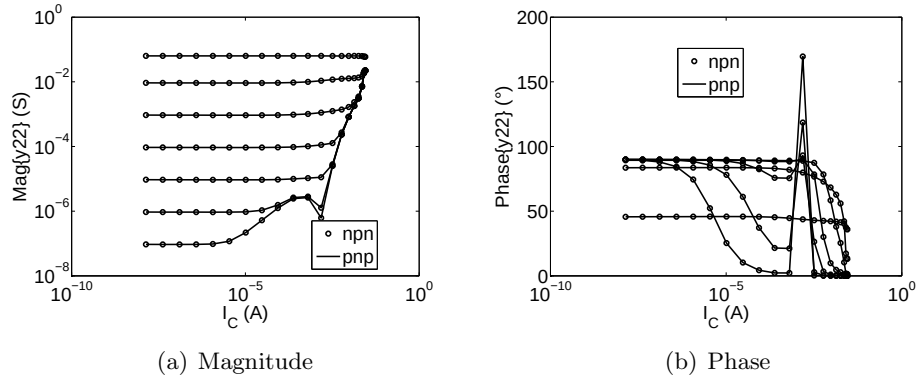


Figure 11.24: Magnitude and phase of Y_{22} versus collector current for $f=1\text{ MHz} \dots 1\text{ THz}$ at $V_{BC} = 0.0V$ and room temperature

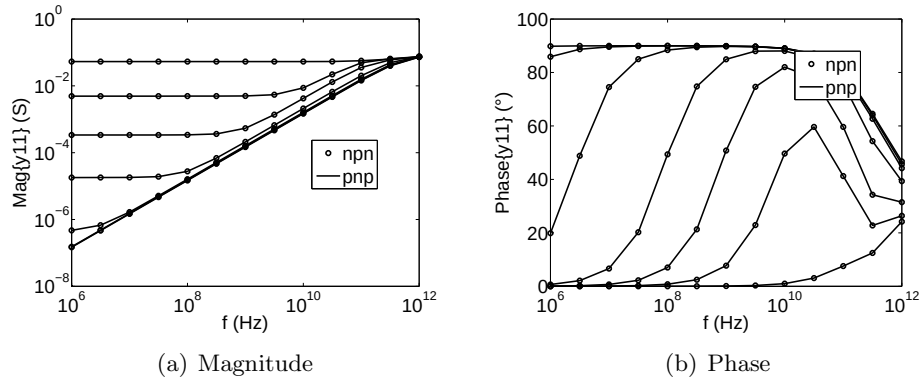


Figure 11.25: Magnitude and phase of Y_{11} versus frequency for $V_{BE} = 0.5 \dots 1.1V$ at $V_{BC} = 0.0V$ and room temperature

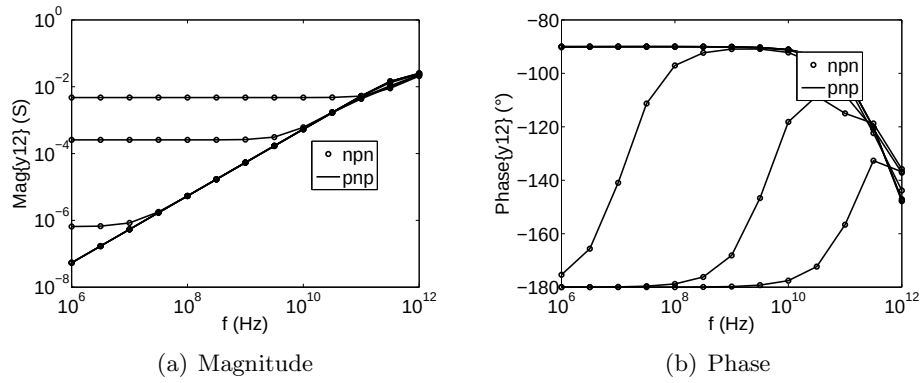


Figure 11.26: Magnitude and phase of Y_{12} versus frequency for $V_{BE} = 0.5 \dots 1.1V$ at $V_{BC} = 0.0V$ and room temperature

11 Special characteristics

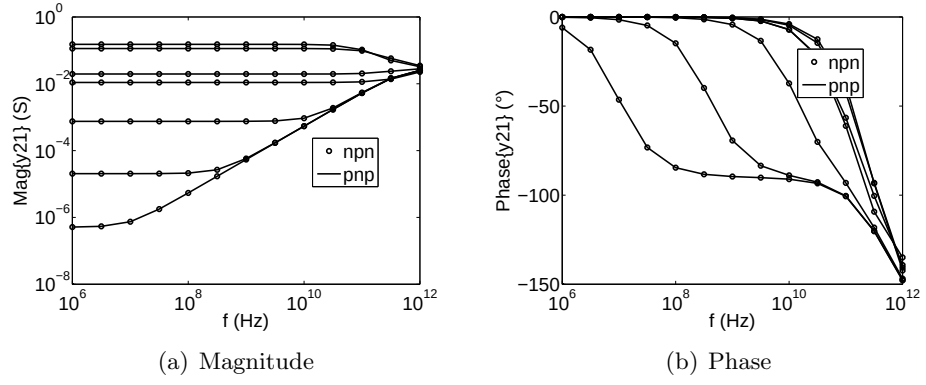


Figure 11.27: Magnitude and phase of Y_{21} versus frequency for $V_{BE} = 0.5 \dots 1.1V$ at $V_{BC} = 0.0V$ and room temperature

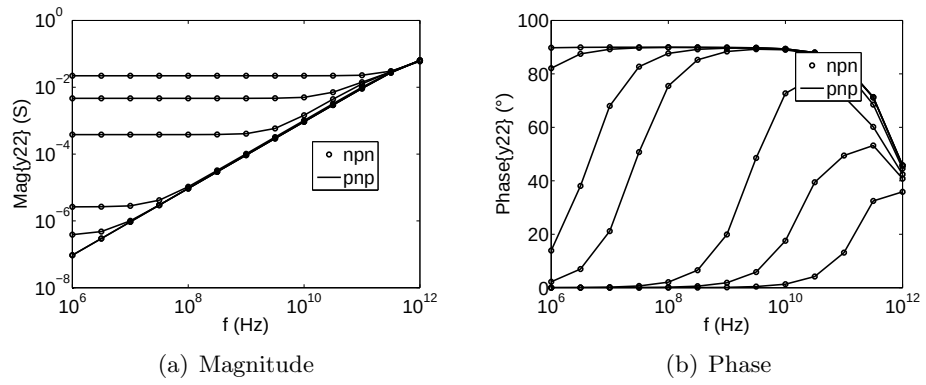


Figure 11.28: Magnitude and phase of Y_{22} versus frequency for $V_{BE} = 0.5 \dots 1.1V$ at $V_{BC} = 0.0V$ and room temperature

11.5.6 Vertical NQS effect

Here, the 1D model card is used.

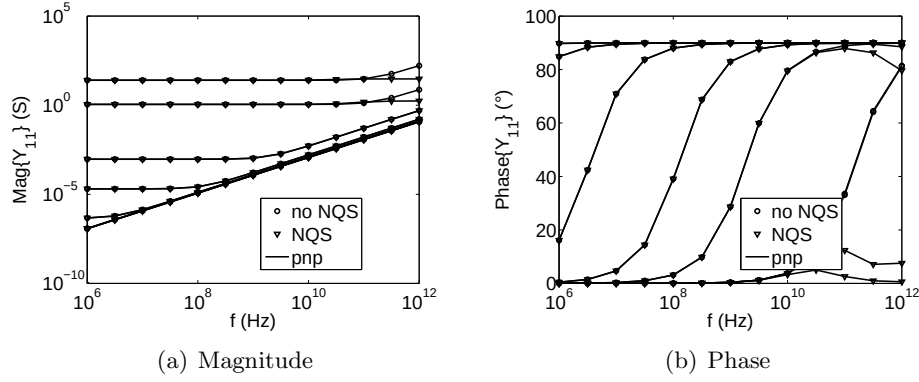


Figure 11.29: Magnitude and phase of Y_{11} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature including and excluding the model for vertical NQS effects.

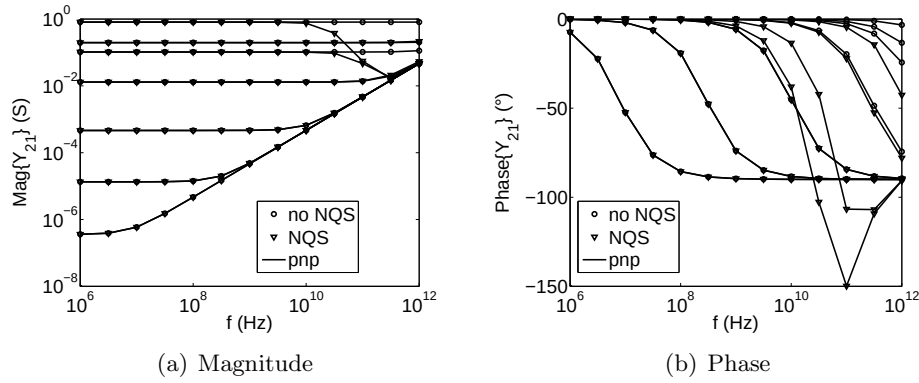


Figure 11.30: Magnitude and phase of Y_{21} versus frequency for $V_{BE} = 0.5...1.1V$ at $V_{BC} = 0.0V$ and room temperature including and excluding the model for vertical NQS effects.

11.5.7 Lateral NQS effect

Here, the model card for the internal transistor including R_{Bi} is used.

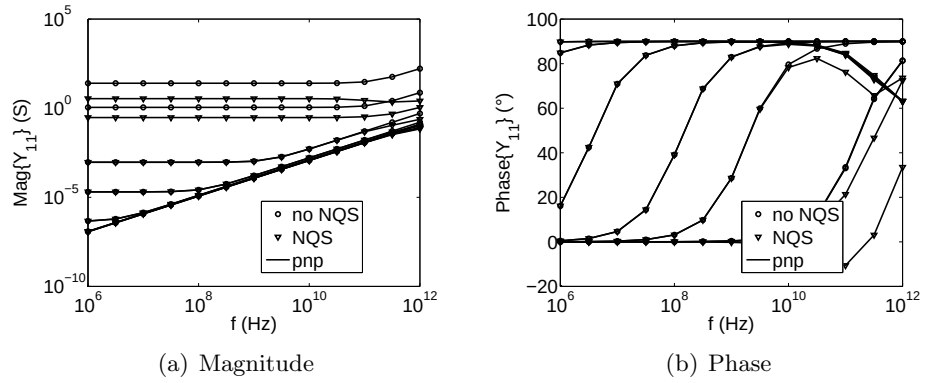


Figure 11.31: Magnitude and phase of Y_{11} versus frequency for $V_{BE} = 0.5 \dots 1.1 \text{ V}$ at $V_{BC} = 0.0 \text{ V}$ and room temperature including and excluding the model for lateral NQS effects.

11.5.8 Correlated noise modeling

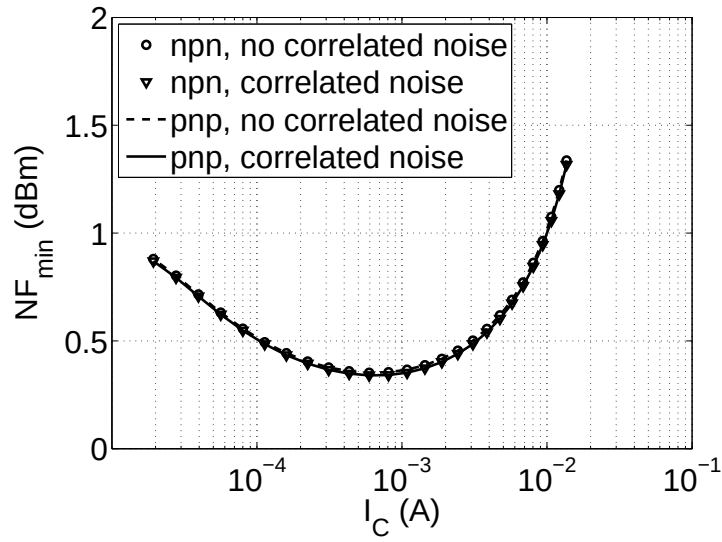


Figure 11.32: Minimum noise figure versus collector current at room temperature including and excluding the modeling of correlated noise.

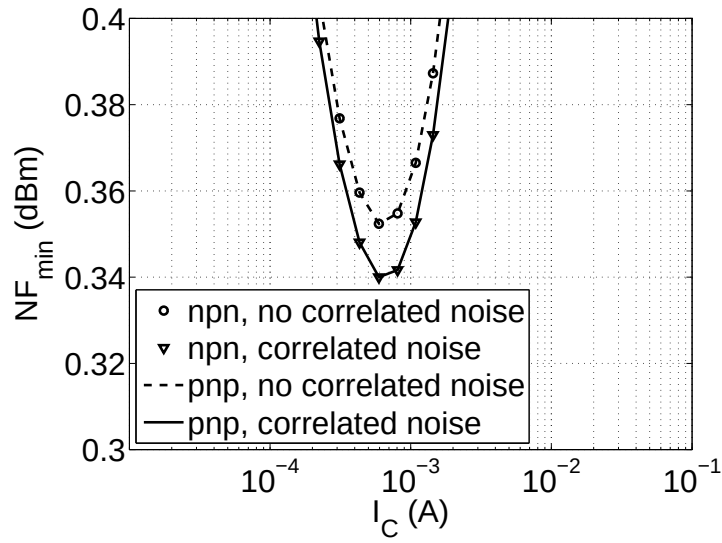


Figure 11.33: Minimum noise figure versus collector current at room temperature including and excluding the modeling of correlated noise.

12 Performance

For performance investigations, the complete transistor including substrate transistor and network and also self-heating is used. A model card excluding and one including the new effects of v2.30/v2.31 were used. All three HICUM versions v2.24, v2.30 and v2.31 were used. V_{BC} is in the range of 0.3...-0.9V.

12.1 Global iteration

12.1.1 Model card for version 2.24

A simulation with a model card of the version 2.24, all three HICUM models give the same number iterations.

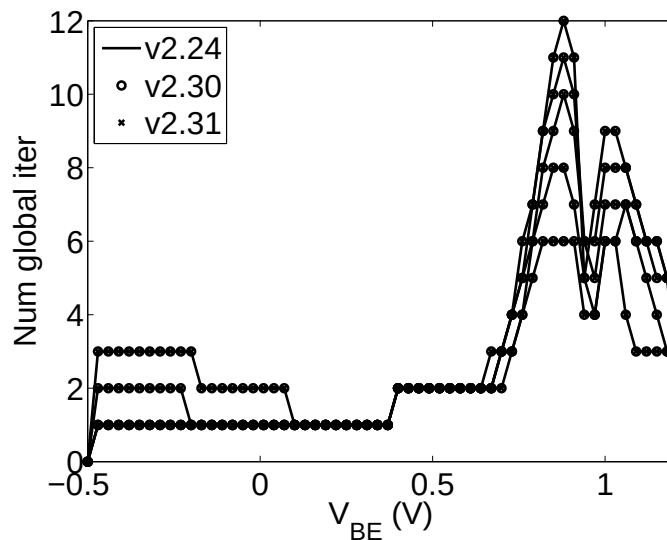


Figure 12.1: Number of global iterations for a version 2.24 model card.

12.1.2 Model card for version 2.31

A simulation with a model card of the version 2.31, the new HICUM versions and therefore the new effects increase the number of iterations. By far the biggest influence comes from the temperature dependent thermal resistance.

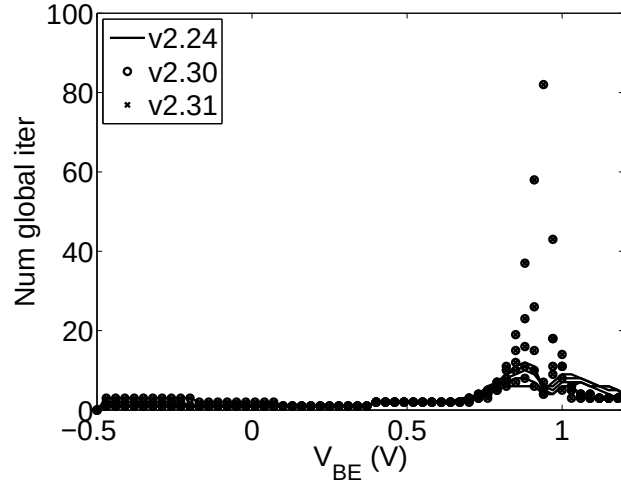


Figure 12.2: Number of global iterations for a version 2.31 model card, including a temperature dependent thermal resistance.

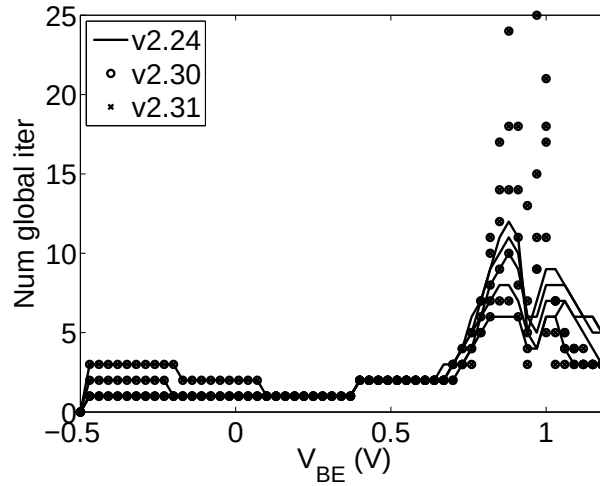


Figure 12.3: Number of global iterations for a version 2.31 model card, using a temperature independent thermal resistance.

12.2 Local iteration

Here, the number of iterations of the internal Newton algorithm is shown.

12.2.1 Model card for version 2.24

A simulation with a model card of the version 2.24, all three HICUM models give the same number of iterations.

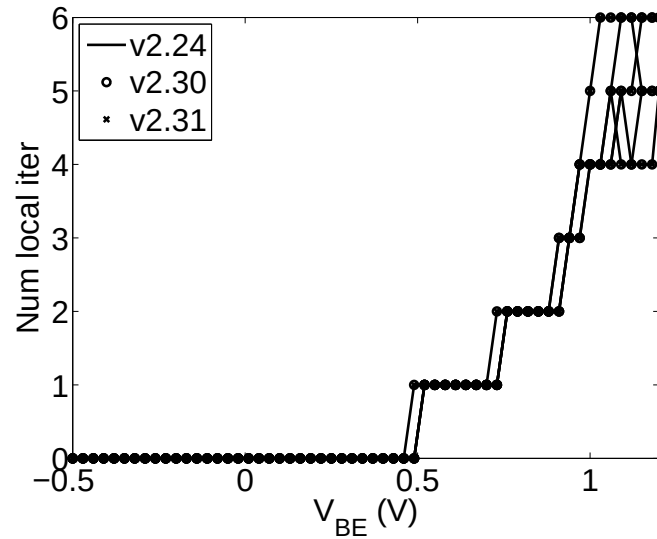


Figure 12.4: Number of local iterations for a version 2.24 model card.

12.2.2 Model card for version 2.31

The usage of the barrier term slightly increases the number of iterations for the newer HICUM versions.

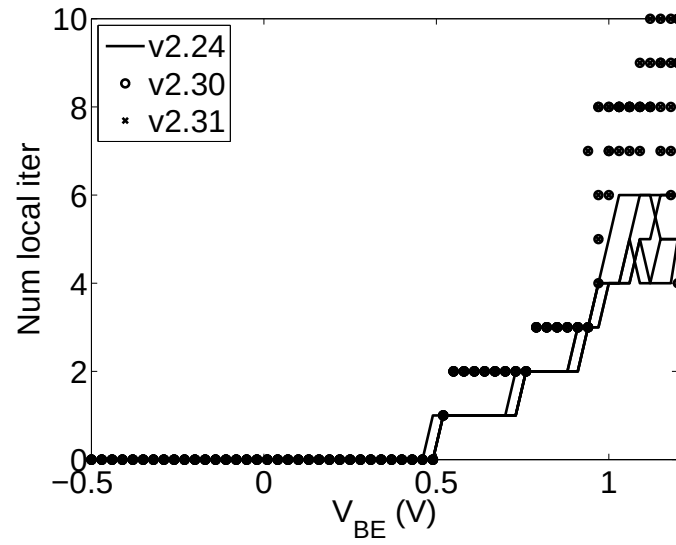


Figure 12.5: Number of local iterations for a version 2.31 model card.

12.3 Simulation time

A simulation with 17000x5 DC operating points was performed. Although the number of iterations is increased for v2.30 and v2.31, the overall simulation time for v2.31 was not increased compared to v2.24.

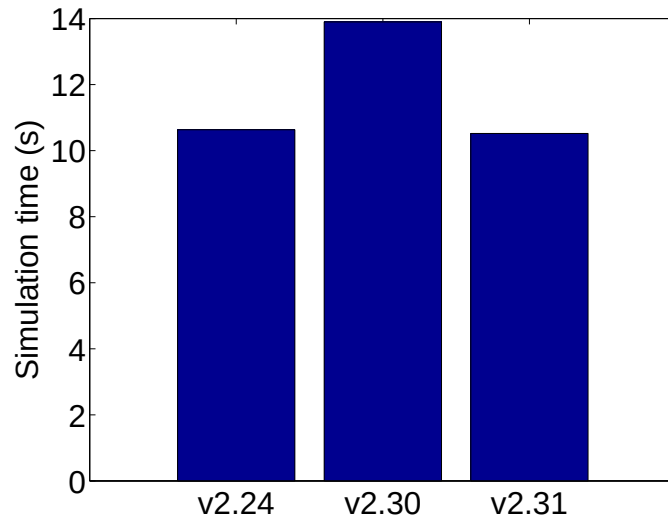


Figure 12.6: Simulation time using the v2.24 model card.

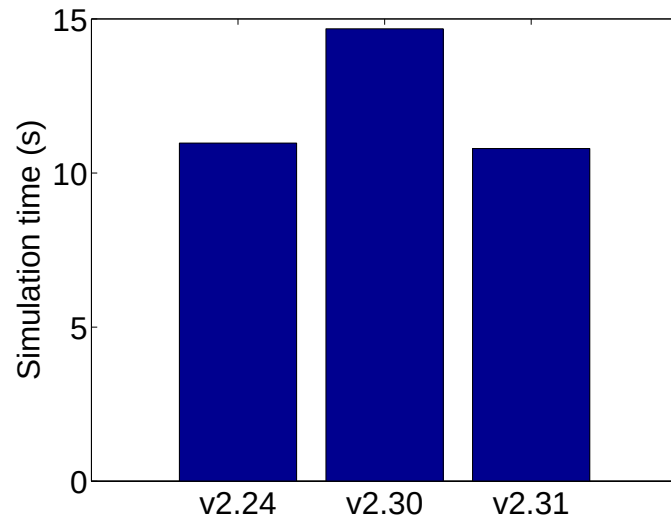


Figure 12.7: Simulation time using the v2.31 model card with temperature dependent thermal resistance.

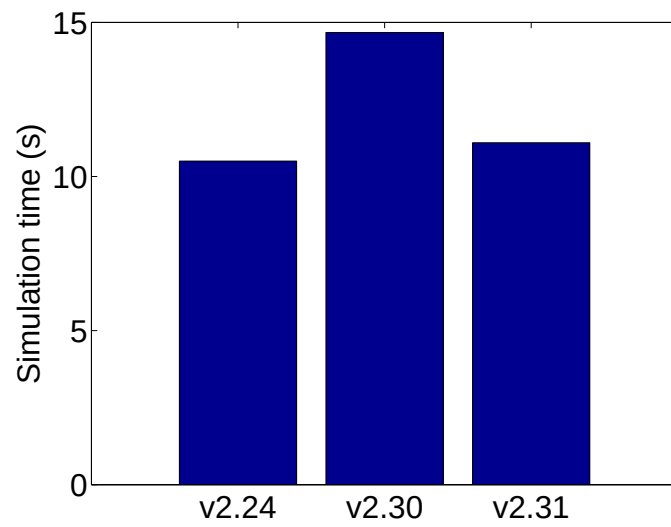


Figure 12.8: Simulation time using the v2.31 model card with temperature independent thermal resistance.