(1, 1)

Modelling polarization in fiberDFB-

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Abstract:

Rare earth doped fiber DFB-lasers are interesting devices both as sensors and as CW-sources for telecommunication applications. We are interested in a sensor configuration where the birefringence of a fiber laser is determined by measuring the beat frequency between two polarization modes. This requires a stable two-polarization laser operation. Other applications require single polarization laser. Both for the single and the dual polarization laser design a proper understanding of the polarization mode competition is required.

We use a transfer-matrix model based on the coupled mode equations to describe the light-propagation in Bragg-gratings with birefringence, twist and gain. Effects of saturation and non-uniformity effects are included in the model. A cavity round trip gain and phase approach is used to find the lasing conditions, like mode frequencies, output intensities and field distribution in the laser cavity.

Both chirp, polarization dependent phase shifts, and polarization dependent coupling strength is shown to cause different thresholds for the polarization modes. Four saturation effects are identified that may influence the mode competition:

1) spatial holeburning related to the overall intensity distribution of the lasing modes,

2) spatial holeburning caused by the difference in phase of the modal standing wave patterns,

3) polarization holeburning caused by the anisotropy of the dopant ions,

4) gain distribution effects related to intensity dependence of pump power absorption.

Effects caused polarization dependence of the pump power absorption will be discussed only briefly.

(1; 2)

mode competition lasers

(1,3)

Polarization imperfections considered:

$\Delta\kappa$	Difference in coupling strength between polarizations
$\Delta\phi_y$	Deviation from optimal $\pi/2$ phaseshift in y polarization (only)
$\Delta\beta_y$	Linear $\pm$ chirp amplitude in the propagation constant of y polarization
r	Twist of birefringence axes (rad/m)

$\lambda_{laser} = 1550$nm

$\lambda_{pump} = 1480$nm

$L_{DFB} = 70$mm

Max gain @ λ_{pump}: 7.2dB/m

(1, 4)

Conclusions:

- We have calculated the regimes of single and dual polarization operation of DFB-lasers for various polarization imperfections.

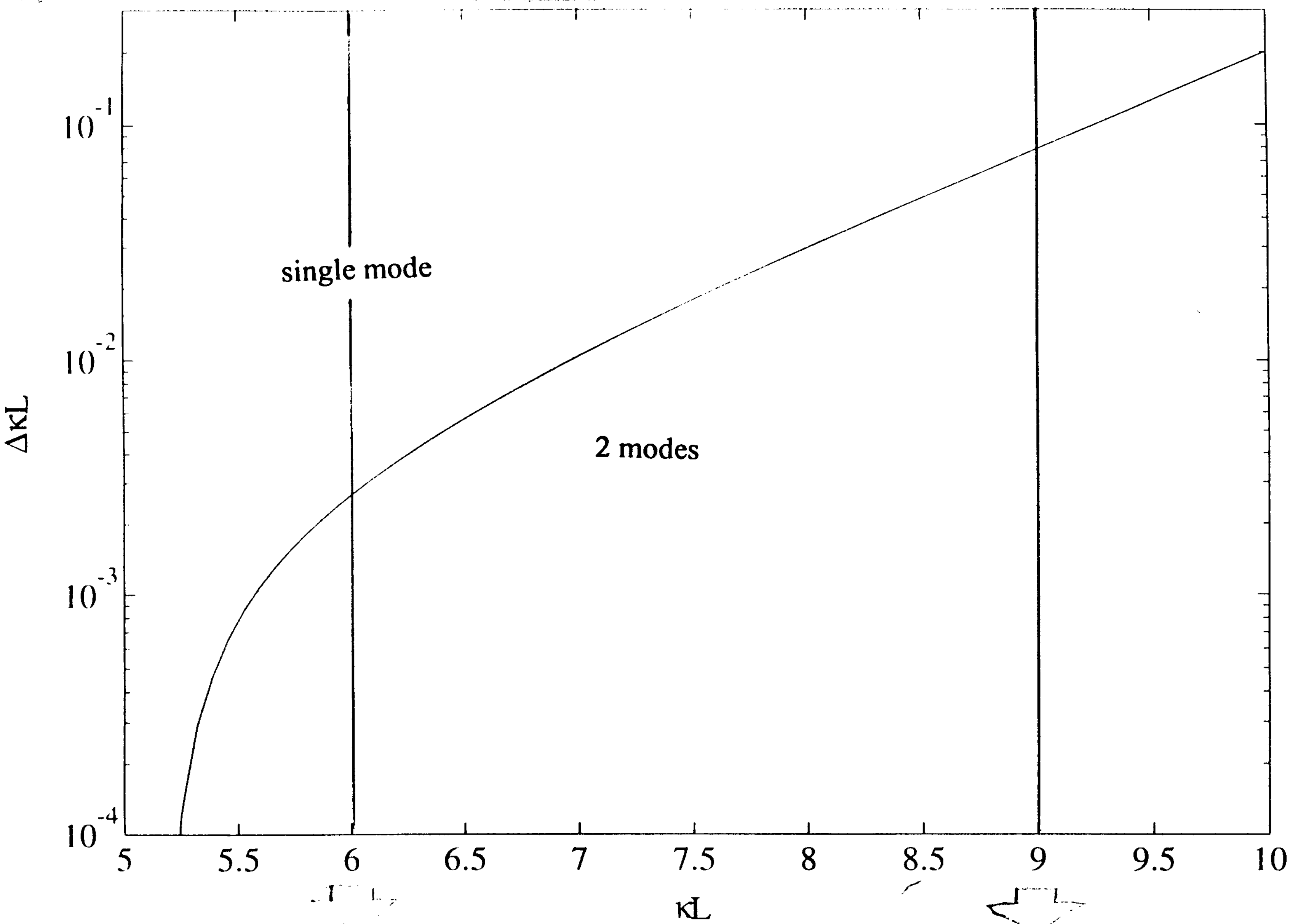
- Polarization dependence of the coupling strength and the central phaseshift seem to be useful parameters for controlling single or dual polarization operation.

- Dual polarization operation in high reflectivity (κL) gratings is much more tolerant to polarization imperfections.

- Both spatial holeburning mechanisms and polarization holeburning mechanisms are important for the understanding of polarization mode competition.

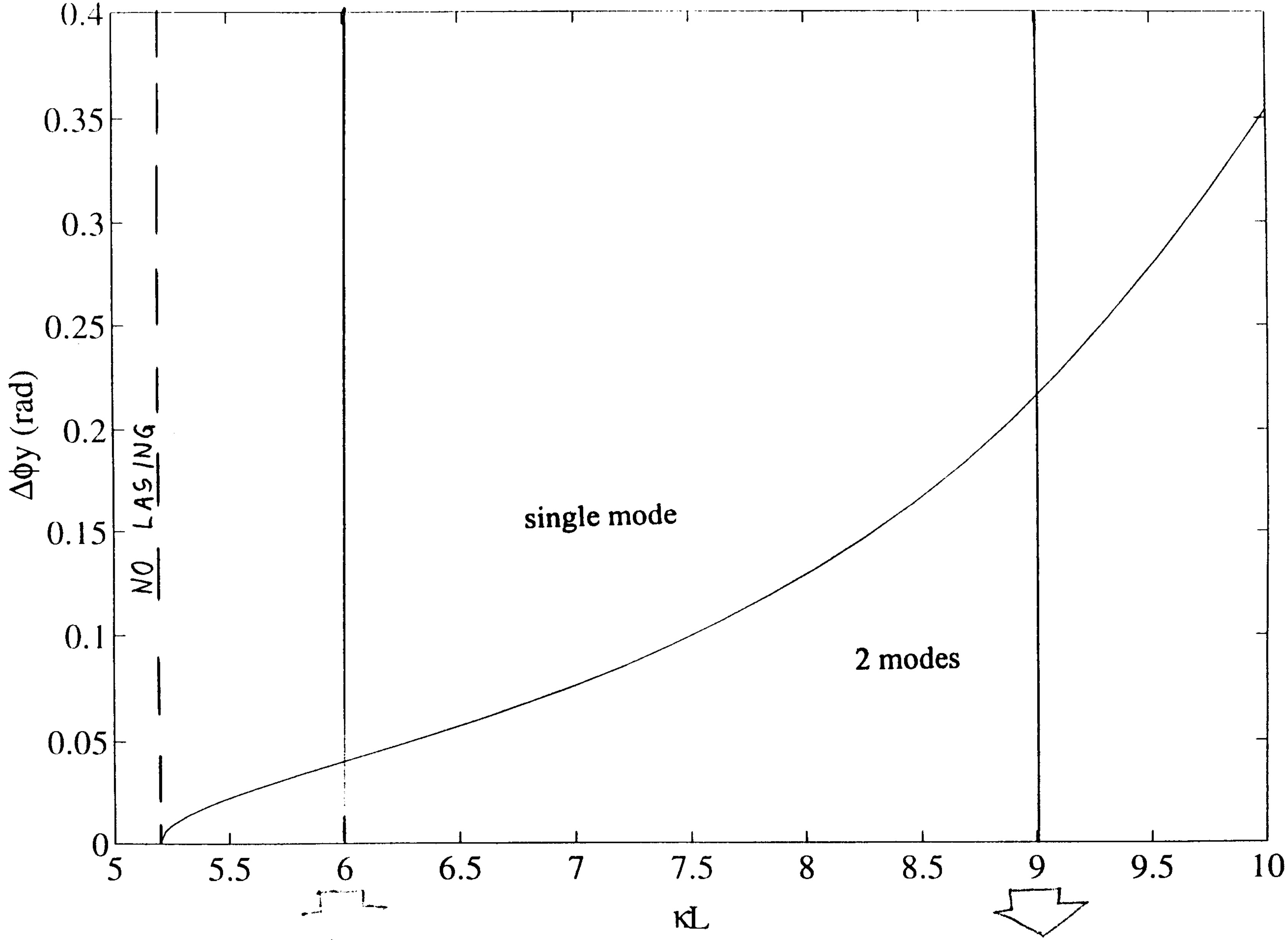
(2,1)

Maximum difference in κL between polarizations, ΔκL, for 2-mode operation at Ip→∞.

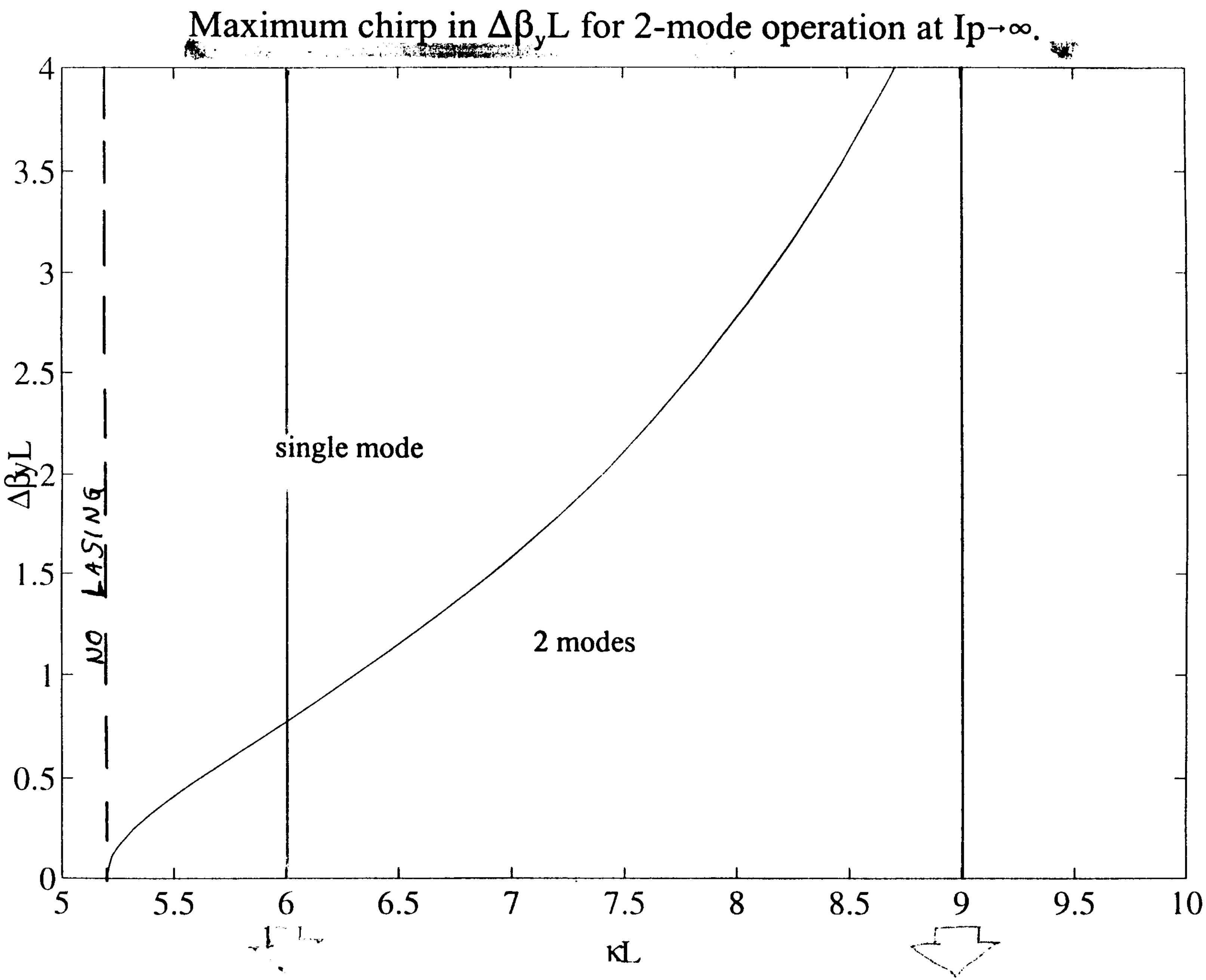


(2, 2)

Maximum phaseshift error of y-mode $\Delta\phi_y$ for 2-mode operation at Ip→∞.



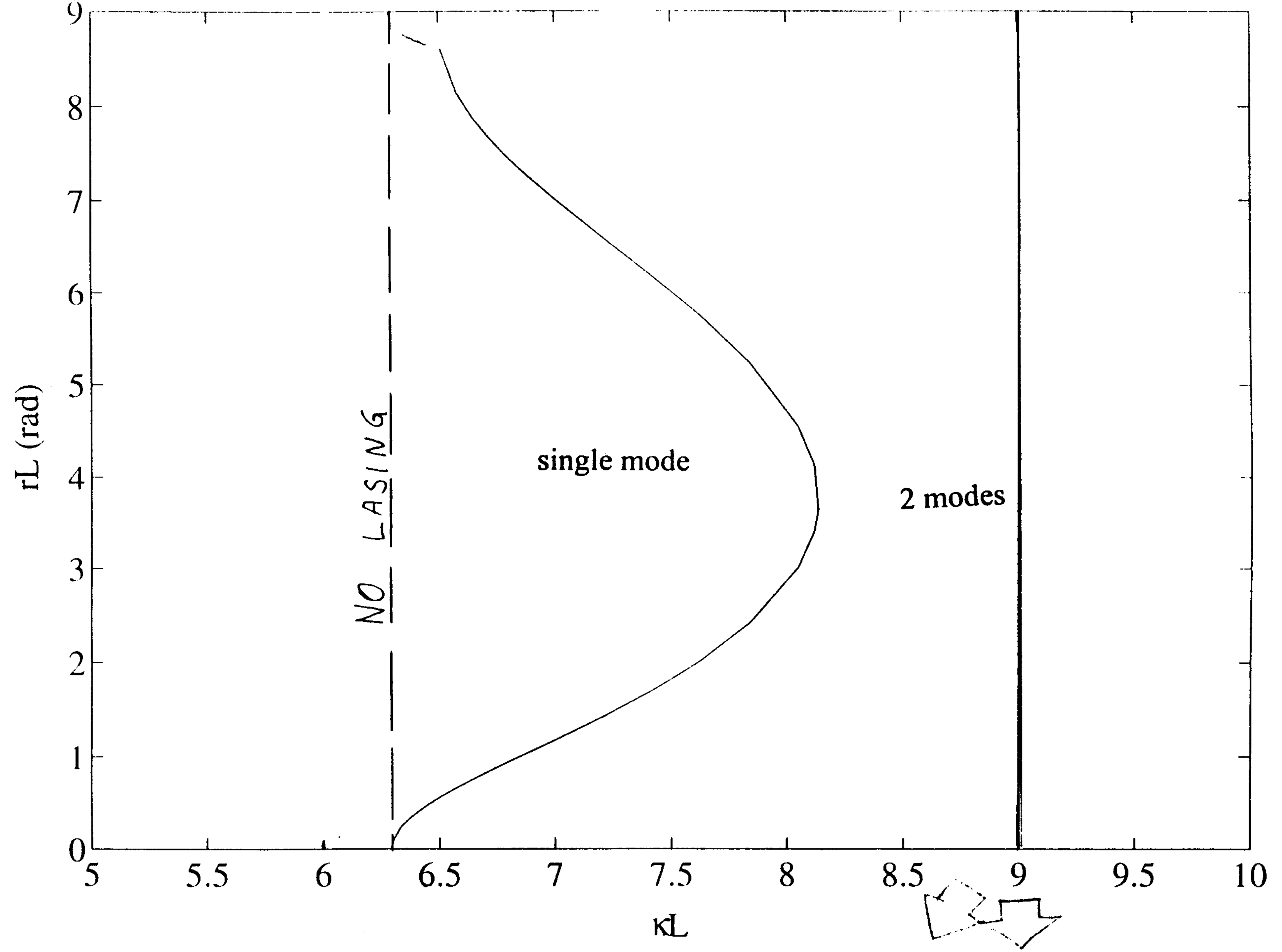
(2,3)



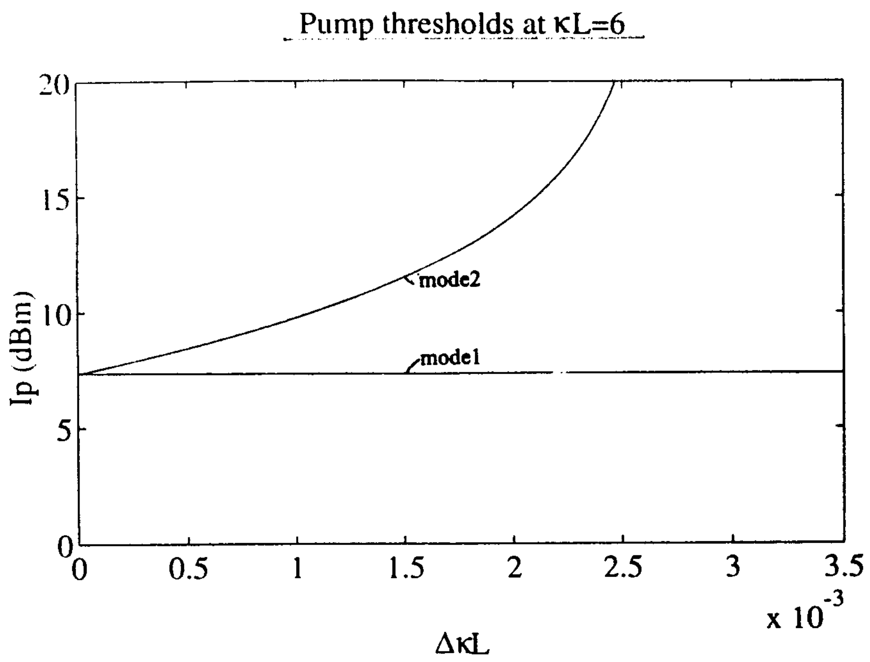
Maximum chirp in ΔβyL for 2-mode operation at Ip→∞.
4
3.5
3
2.5
2
1.5
1
0.5
0
5
5.5
6
6.5
7
7.5
8
8.5
9
9.5
10
ΔβyL
κL
NO LASING
single mode
2 modes

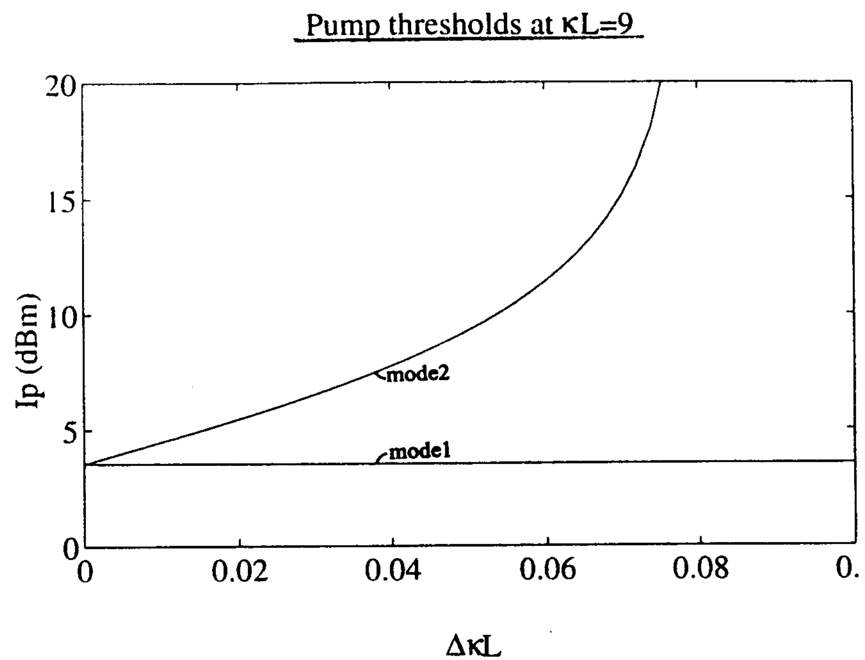
(2,4)

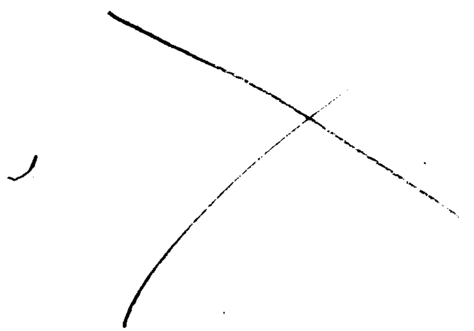
Maximum effective twist rate rL for 2-mode operation at Ip→∞. $\Delta\phi_y$=0.05rad.



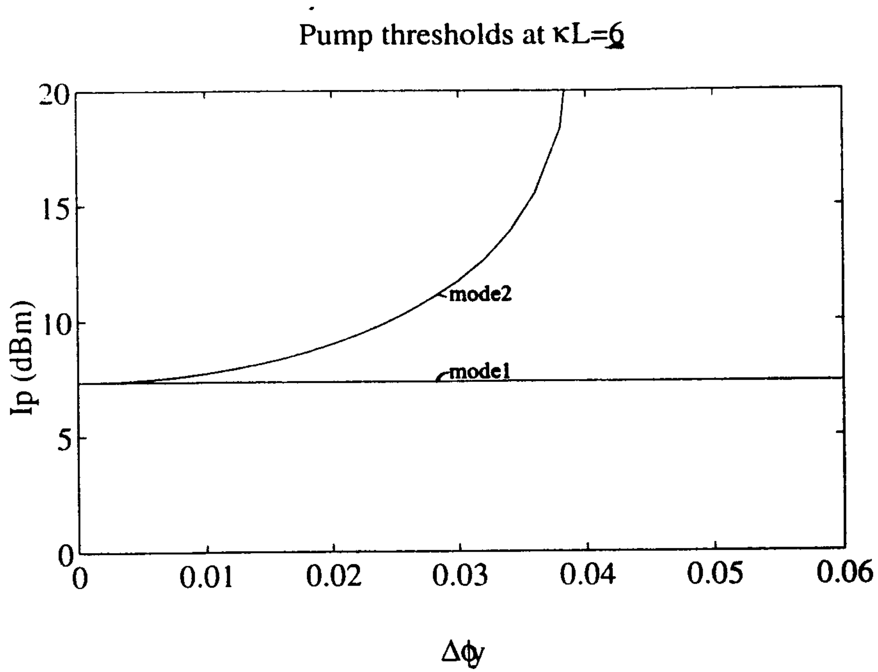
(3, 1)

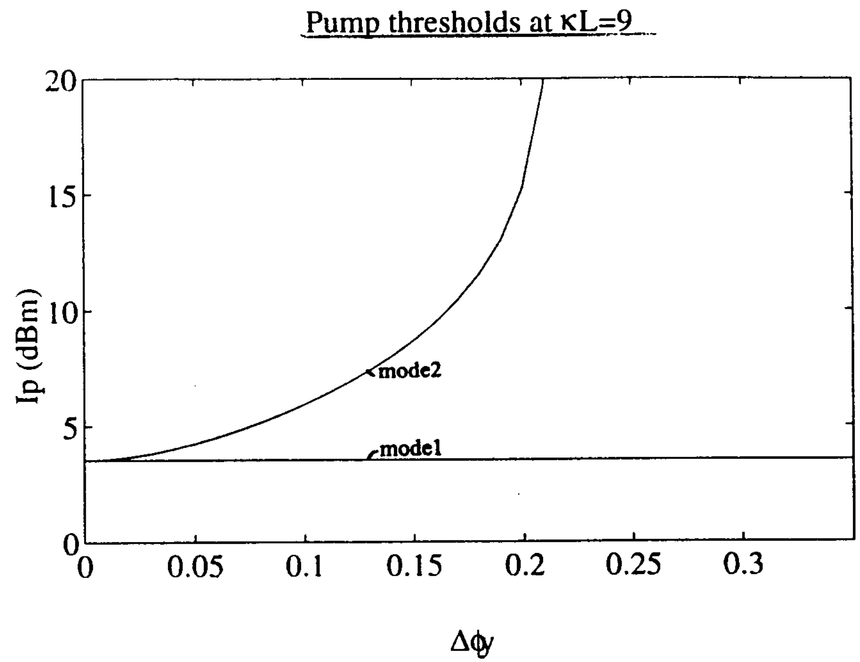

Pump thresholds at κL=6
Ip (dBm)
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
x 10^-3
ΔκL
mode2
mode1

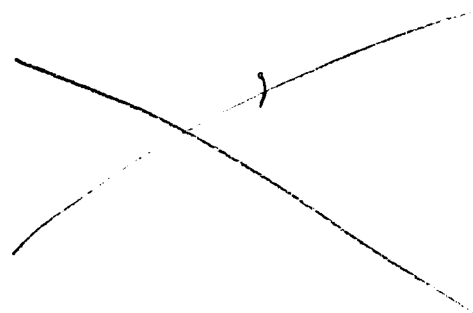

Pump thresholds at κL=9
Ip (dBm)
20
15
10
5
0
0
0.02
0.04
0.06
0.08
0.1
ΔκL
mode2
mode1



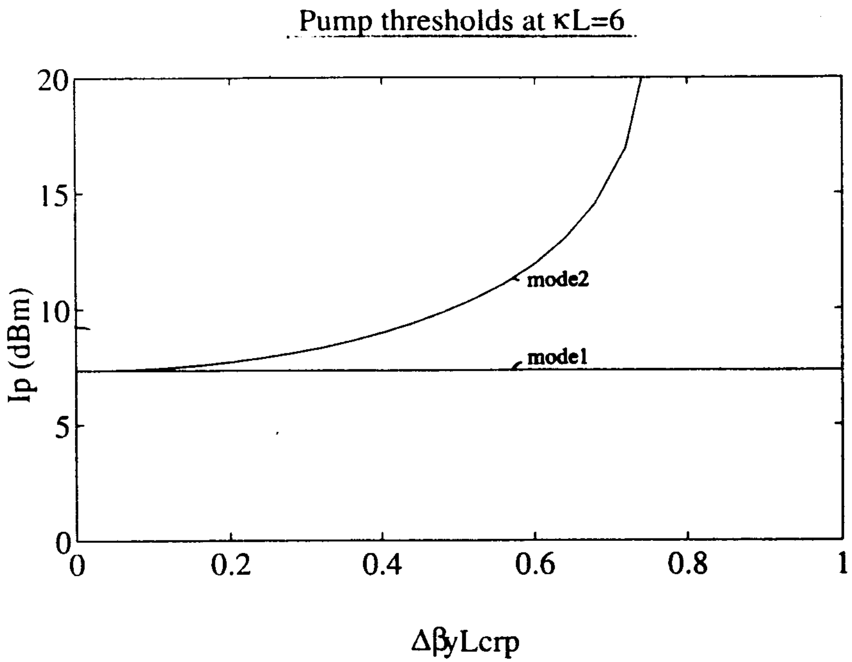
(3,2)


Pump thresholds at κL=6
Ip (dBm)
mode2
mode1
0
5
10
15
20
0.01
0.02
0.03
0.04
0.05
0.06
Δφy

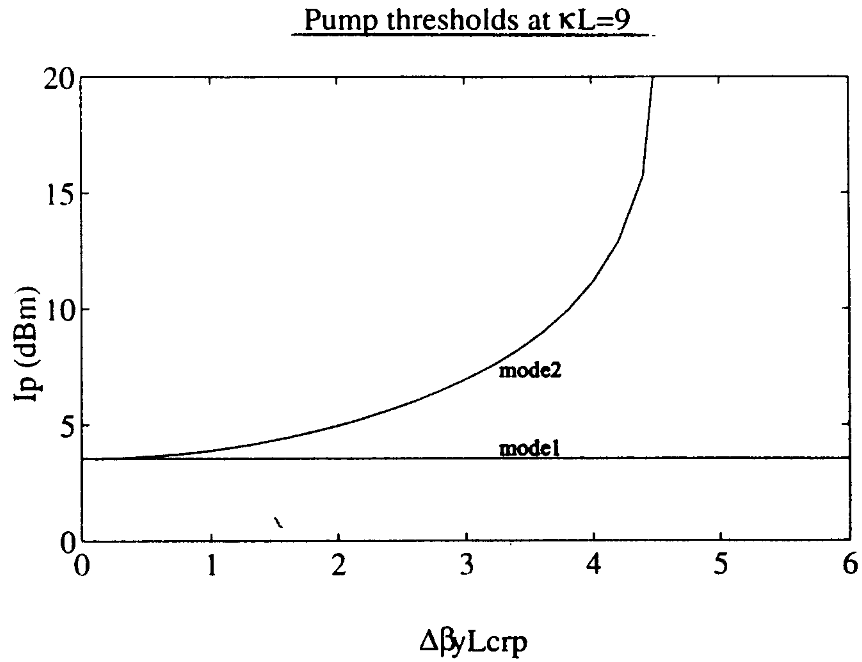

Pump thresholds at κL=9
Ip (dBm)
mode2
mode1
0
5
10
15
20
0.05
0.1
0.15
0.2
0.25
0.3
Δφy



(3,3)



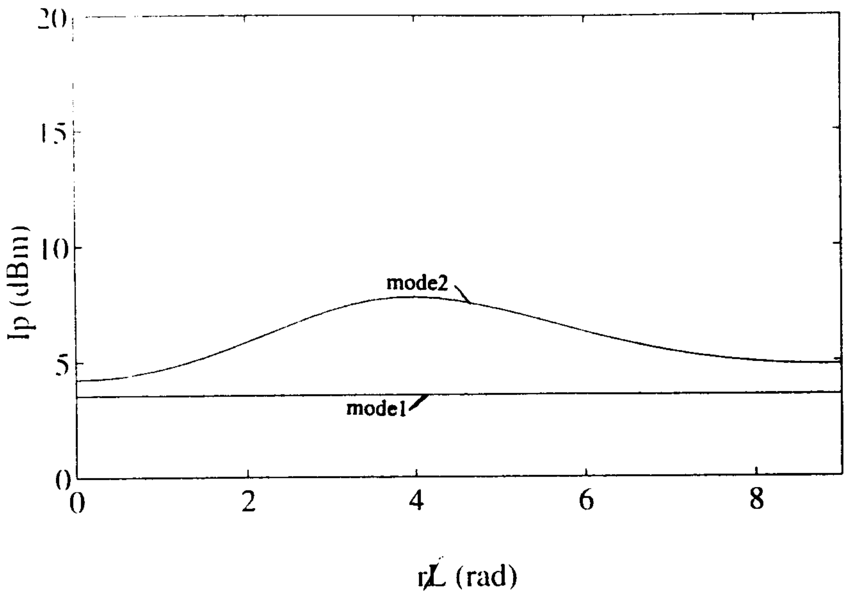
Pump thresholds at κL=6
Ip (dBm)
ΔβyLcrp
mode2
mode1
0
5
10
15
20
0
0.2
0.4
0.6
0.8
1



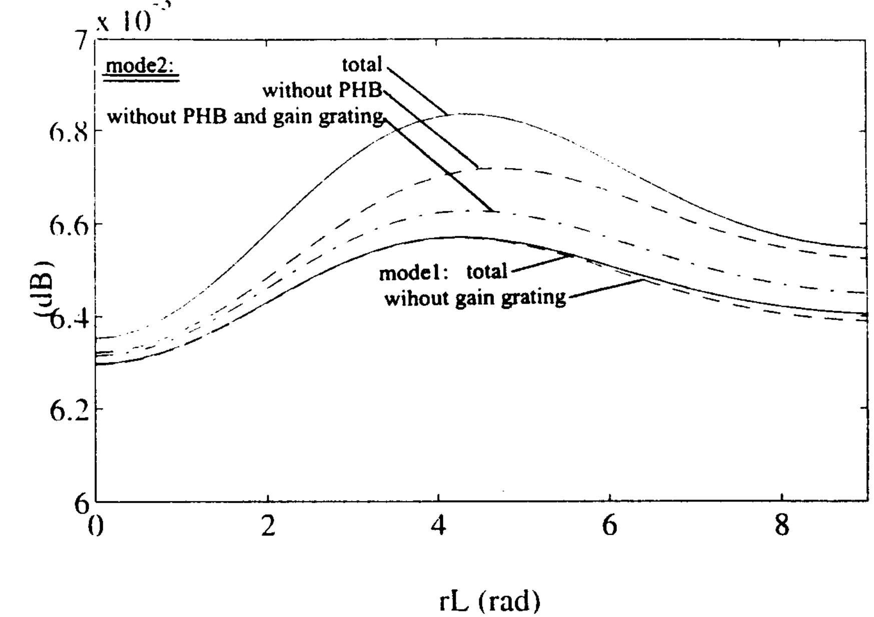
Pump thresholds at κL=9
Ip (dBm)
ΔβyLcrp
mode2
mode1
0
5
10
15
20
0
1
2
3
4
5
6

(3,4)

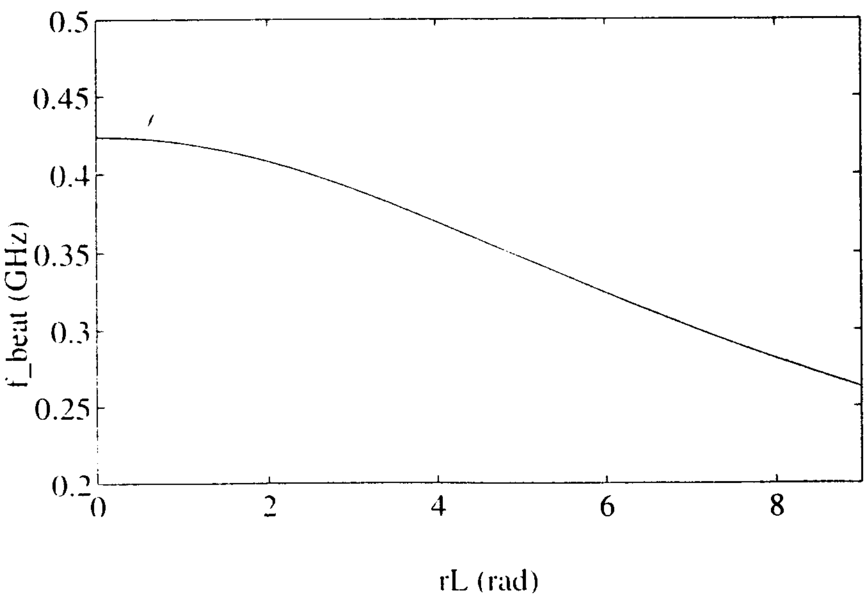
Pump thresholds at κL=9



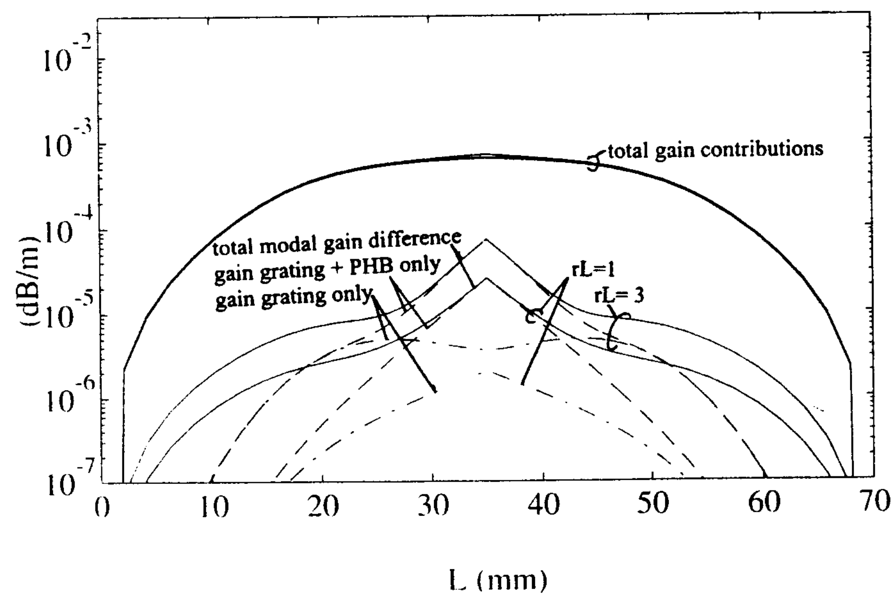
Roundtrip gain contributions at Ip=20mW, κL=9



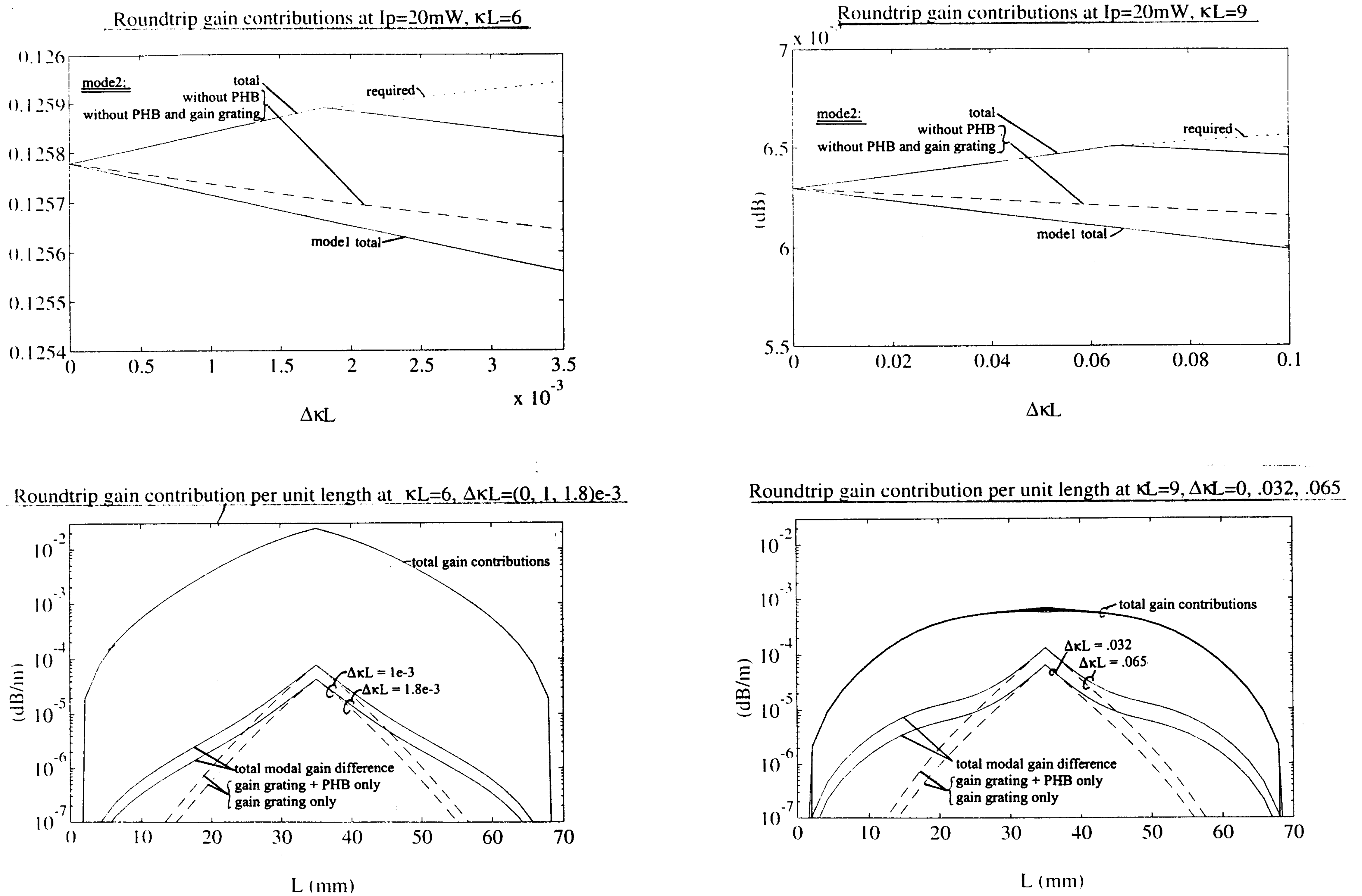
Beat frequency at Ip=20mW (13dBm), κL=9



Roundtrip gain contribution per unit length at κL=9, rL=(1, 3) rad



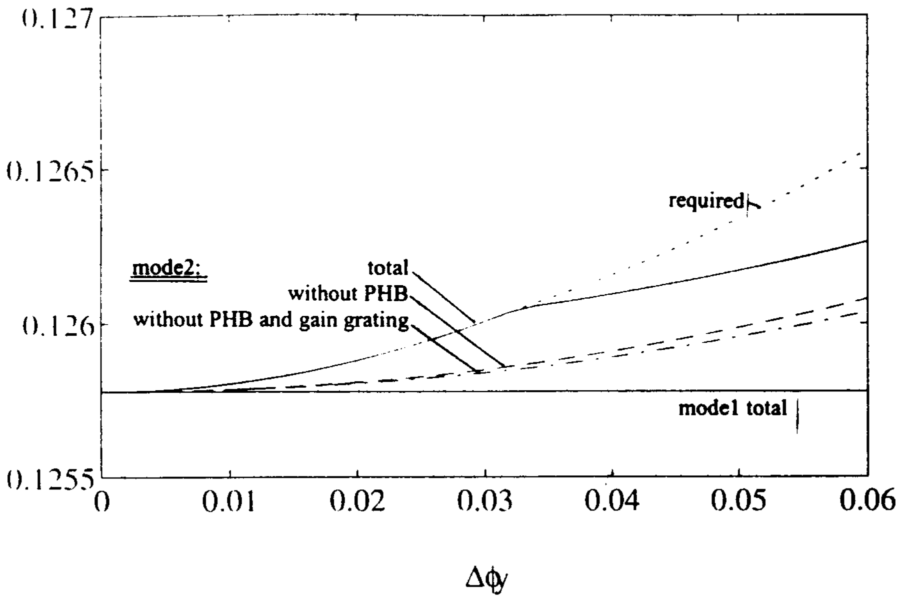
(4.1)



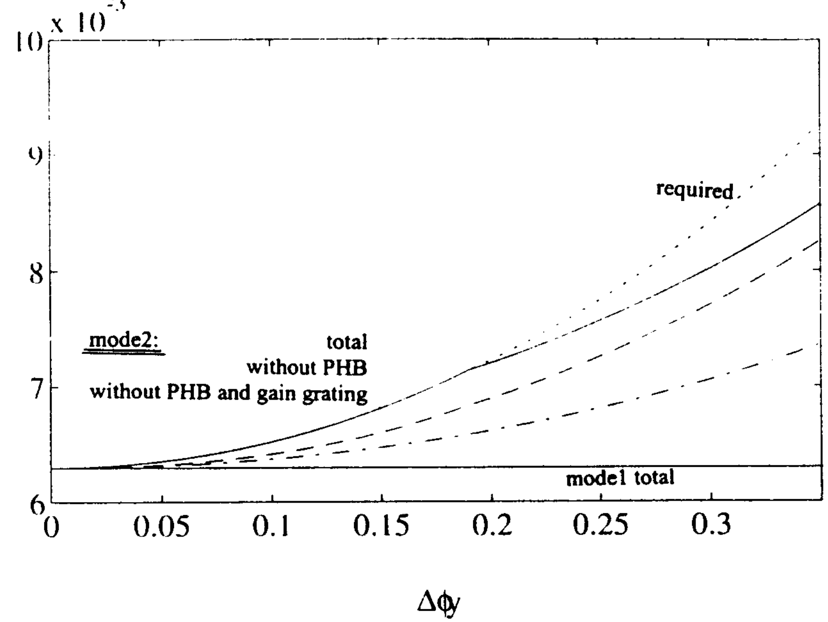
Roundtrip gain contributions at Ip=20mW, κL=6
mode2:
total
without PHB
without PHB and gain grating
required
mode1 total
0.126
0.1259
0.1258
0.1257
0.1256
0.1255
0.1254
0
0.5
1
1.5
2
2.5
3
3.5
x 10^-3
ΔκL
Roundtrip gain contributions at Ip=20mW, κL=9
x 10
7
6.5
6
5.5
(dB)
0
0.02
0.04
0.06
0.08
0.1
ΔκL
Roundtrip gain contribution per unit length at κL=6, ΔκL=(0, 1, 1.8)e-3
total gain contributions
ΔκL = 1e-3
ΔκL = 1.8e-3
total modal gain difference
gain grating + PHB only
gain grating only
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
(dB/m)
0
10
20
30
40
50
60
70
L (mm)
Roundtrip gain contribution per unit length at κL=9, ΔκL=0, .032, .065
total gain contributions
ΔκL = .032
ΔκL = .065
total modal gain difference
gain grating + PHB only
gain grating only
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
(dB/m)
0
10
20
30
40
50
60
70
L (mm)

(4,2)

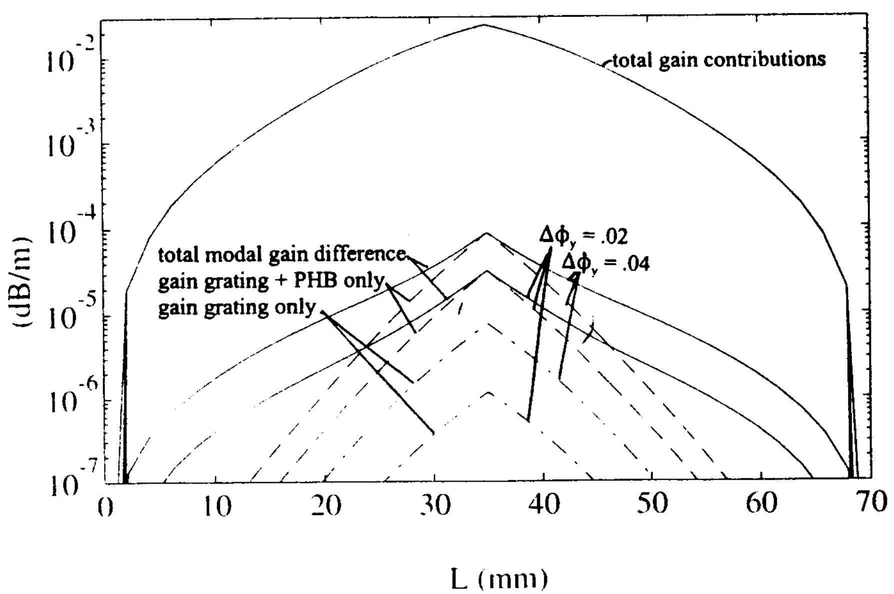
Roundtrip gain contributions at Ip=20mW, κL=6



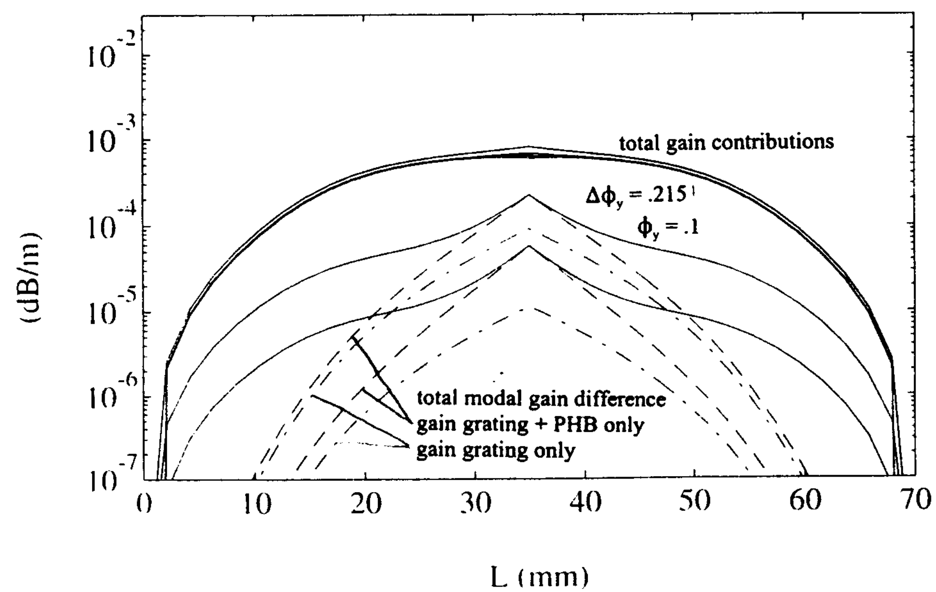
Roundtrip gain contributions at Ip=20mW, κL=9



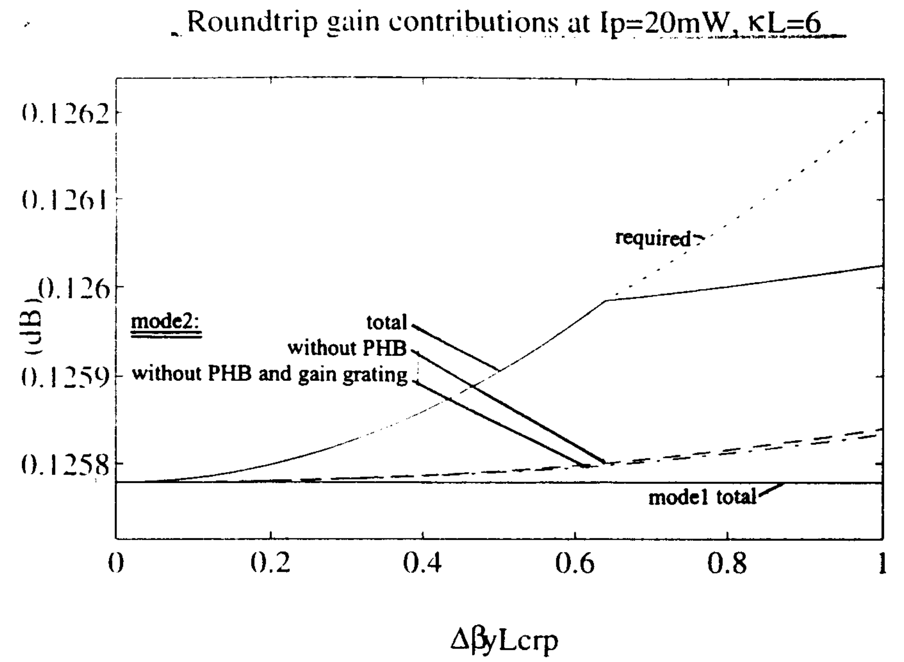
Roundtrip gain contribution per unit length at κL=6, Δφy=(0, 20, 40)e-3

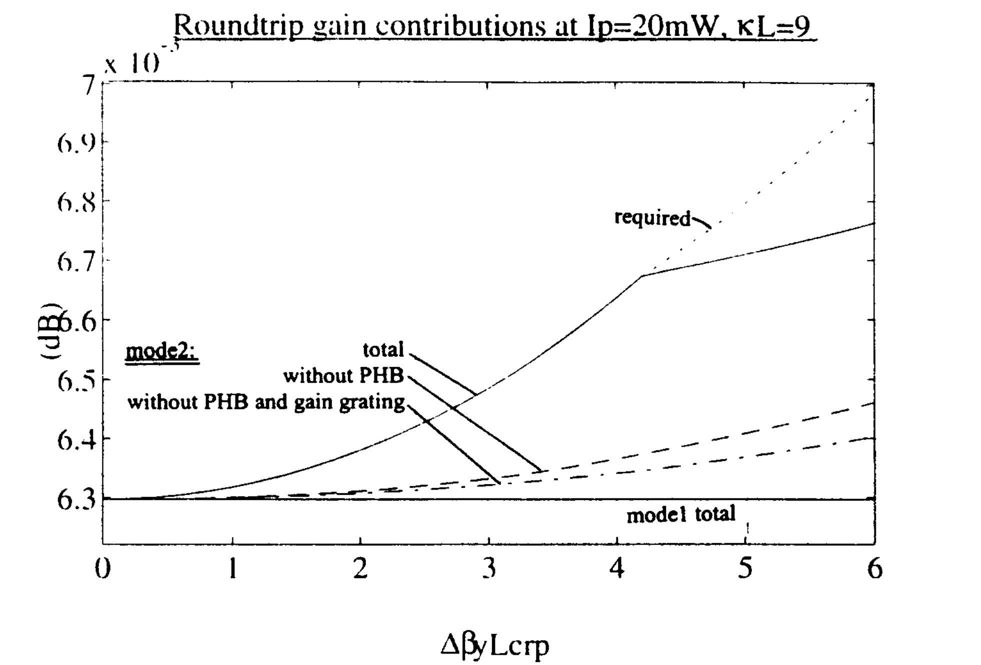


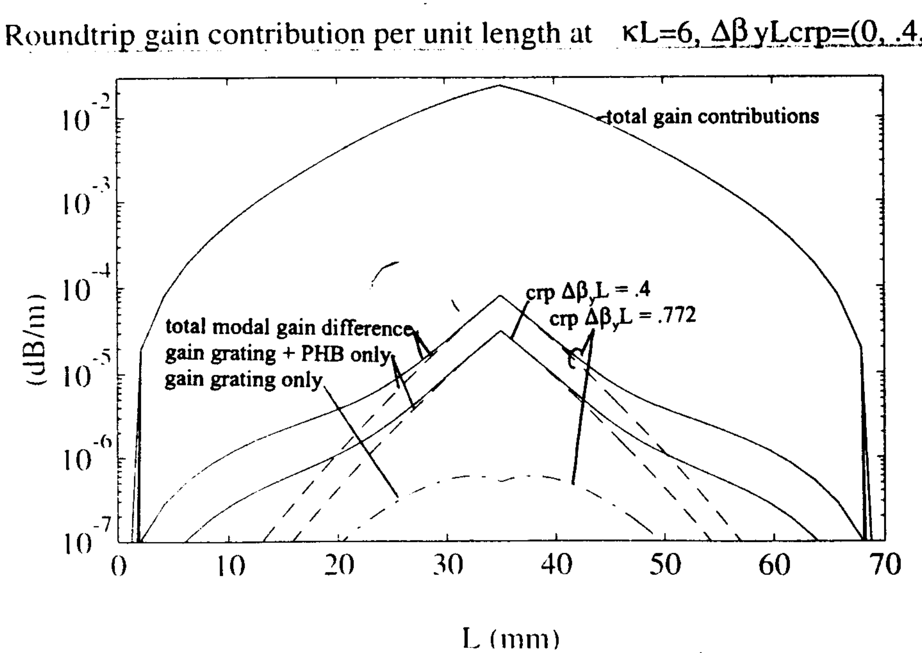
Roundtrip gain contribution per unit length at κL=9, Δφy=(0, .1, .215)

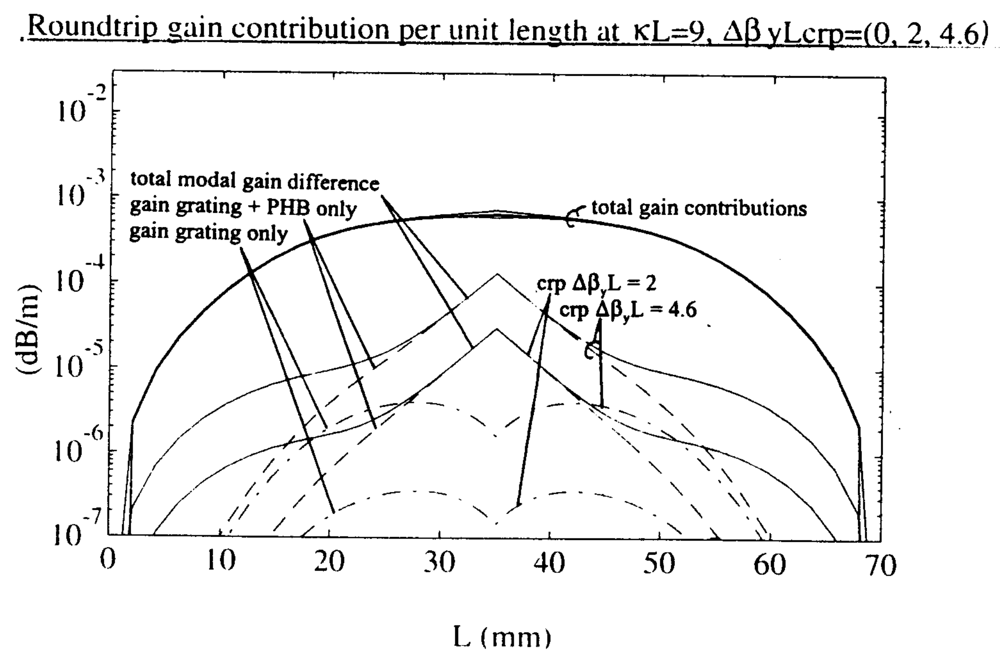


(4,3)


Roundtrip gain contributions at Ip=20mW, κL=6
(dB)
0.1258
0.1259
0.126
0.1261
0.1262
mode2:
total
without PHB
without PHB and gain grating
required
model total
0
0.2
0.4
0.6
0.8
1
ΔβyLcrp

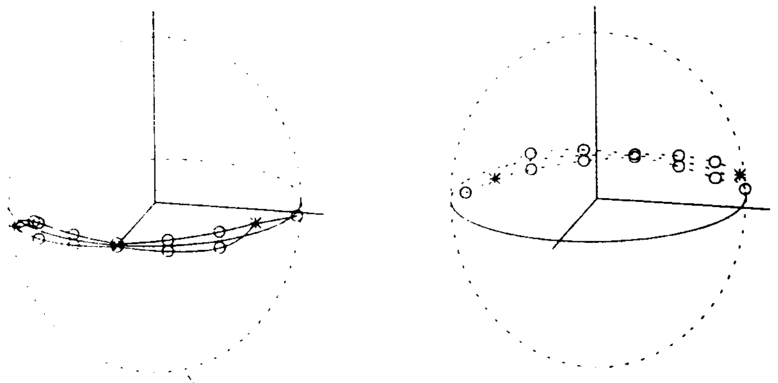

Roundtrip gain contributions at Ip=20mW, κL=9
x 10^-3
(dB)
6.3
6.4
6.5
6.6
6.7
6.8
6.9
7
mode2:
total
without PHB
without PHB and gain grating
required
model total
0
1
2
3
4
5
6
ΔβyLcrp


Roundtrip gain contribution per unit length at κL=6, Δβ yLcrp=(0, .4, .772)
(dB/m)
10^-7
10^-6
10^-5
10^-4
10^-3
10^-2
total gain contributions
total modal gain difference
gain grating + PHB only
gain grating only
crp Δβ_yL = .4
crp Δβ_yL = .772
0
10
20
30
40
50
60
70
L (mm)


Roundtrip gain contribution per unit length at κL=9, Δβ yLcrp=(0, 2, 4.6)
(dB/m)
10^-7
10^-6
10^-5
10^-4
10^-3
10^-2
total modal gain difference
gain grating + PHB only
gain grating only
total gain contributions
crp Δβ_yL = 2
crp Δβ_yL = 4.6
0
10
20
30
40
50
60
70
L (mm)

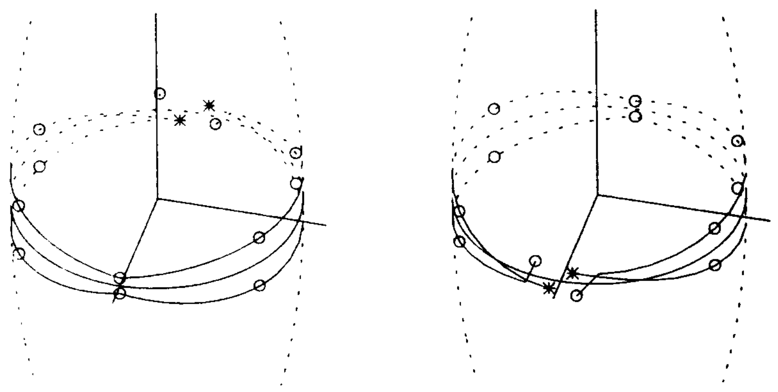
(4,4)

Left and right propagating SOP`s vs. position. rL=1. Ip=20mW



mode1 mode2

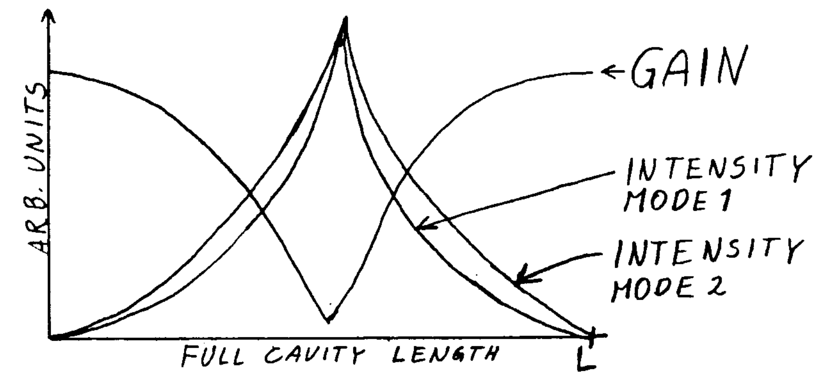
Left and right propagating SOP`s vs. position. rL=3, Ip=20mW



mode1 mode2

SPATIAL HOLEBURNING EFFECTS:

GLOBAL HOLEBURNING



LOCAL HOLEBURNING CAUSED BY GAIN GRATING