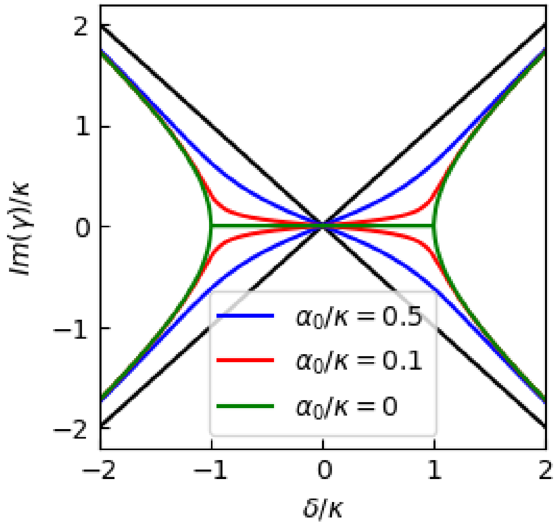


# Coupled Wave Theory of Distributed Feedback Lasers

**Jan Genoe (jan.genoe@imec.be)**

**Mar 23, 2023**

# CONTENTS

This repository applies the calculations of Kogelnik and Shank in J. Appl. Phys. 43, 2327 (1972) [1] to a few use cases. The calculations have been validated by replotting the graphs from [1].

# Table of contents



[1] H. Kogelnik and C. V. Shank, Coupled Wave Theory of Distributed Feedback Lasers. Journal of Applied Physics, 43 (1972) 2327–2335. https://doi.org/10.1063/1.1661499.

CHAPTER

ONE

# COUPLED-WAVE THEORY OF DISTRIBUTED FEEDBACK LASERS

This page comprises simulations from the manuscript H. Kogelnik and C. V. Shank, *Coupled-Wave Theory of Distributed Feedback Lasers*. Journal of Applied Physics, **43** (1972) 2327–2335. doi:10.1063/1.1661499

We compare the different simulations in the paper with our code.

## 1.1 Dispersion diagram for index modulation for various gain to coupling parameter ratios

Fig. 1.1 calculates the dispersion diagram for index modulation for various gain ($\alpha_o$) to coupling ($\kappa$) parameter ratios. In case of index modulation we have that $\kappa = \pi n_1/\lambda_o$. We observe that the calculated result fits the result from [1], as can be seen in Fig. 1.2.

## 1.2 Dispersion diagram for gain modulation for various gain to coupling parameter ratios

Fig. 1.3 calculates the dispersion diagram for index modulation for various gain ($\alpha_o$) to coupling ($\kappa$) parameter ratios. In case of index modulation we have that $\kappa = \frac{1}{2}j\alpha_1$. We observe that the calculated result fits Fig. 1.4.

## 1.3 Mode spectrum for index coupling

## 1.4 Mode spectrum for gain coupling

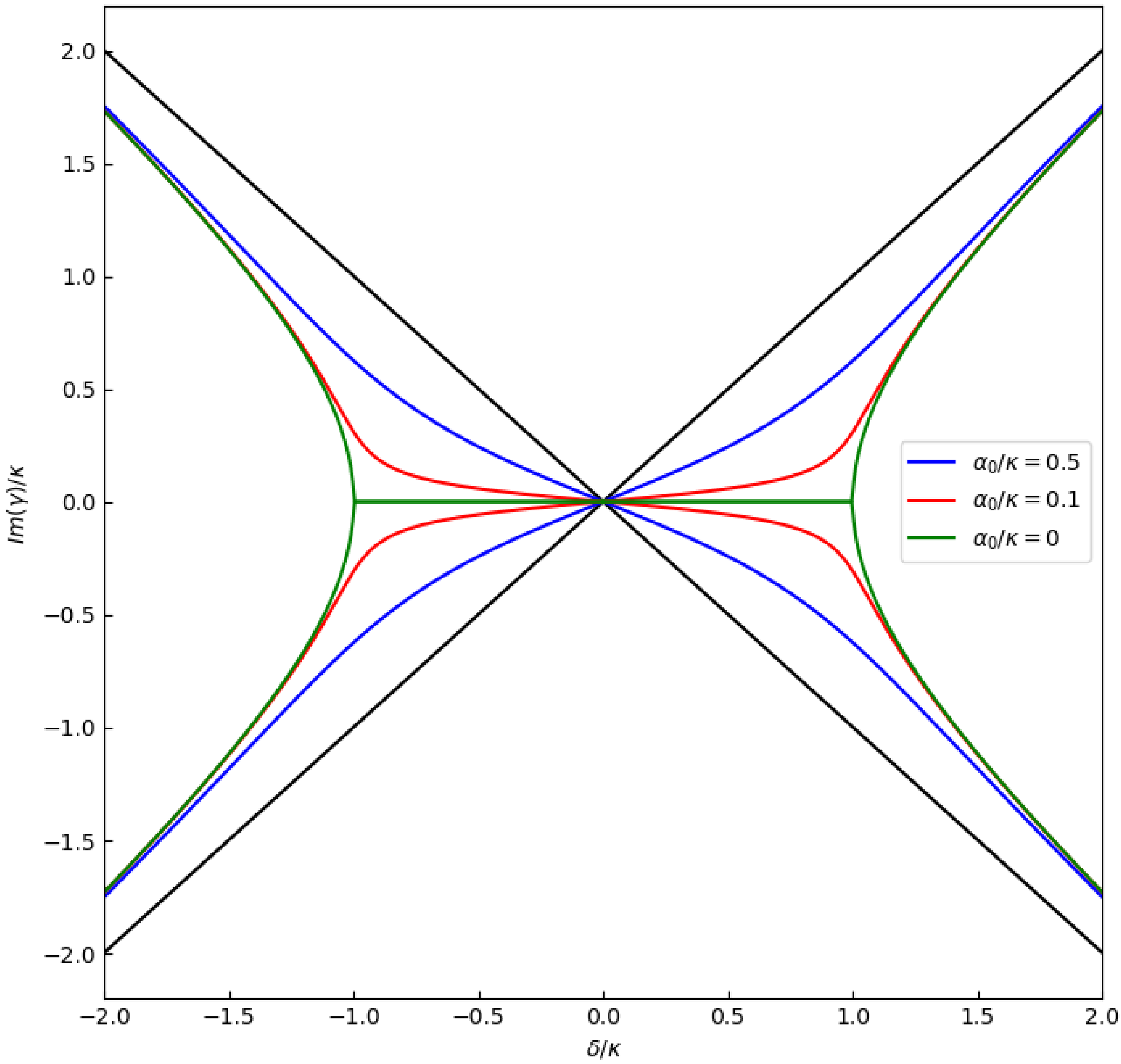


Fig. 1.1: Calculated dispersion diagram for index modulation for various gain to coupling parameter ratios

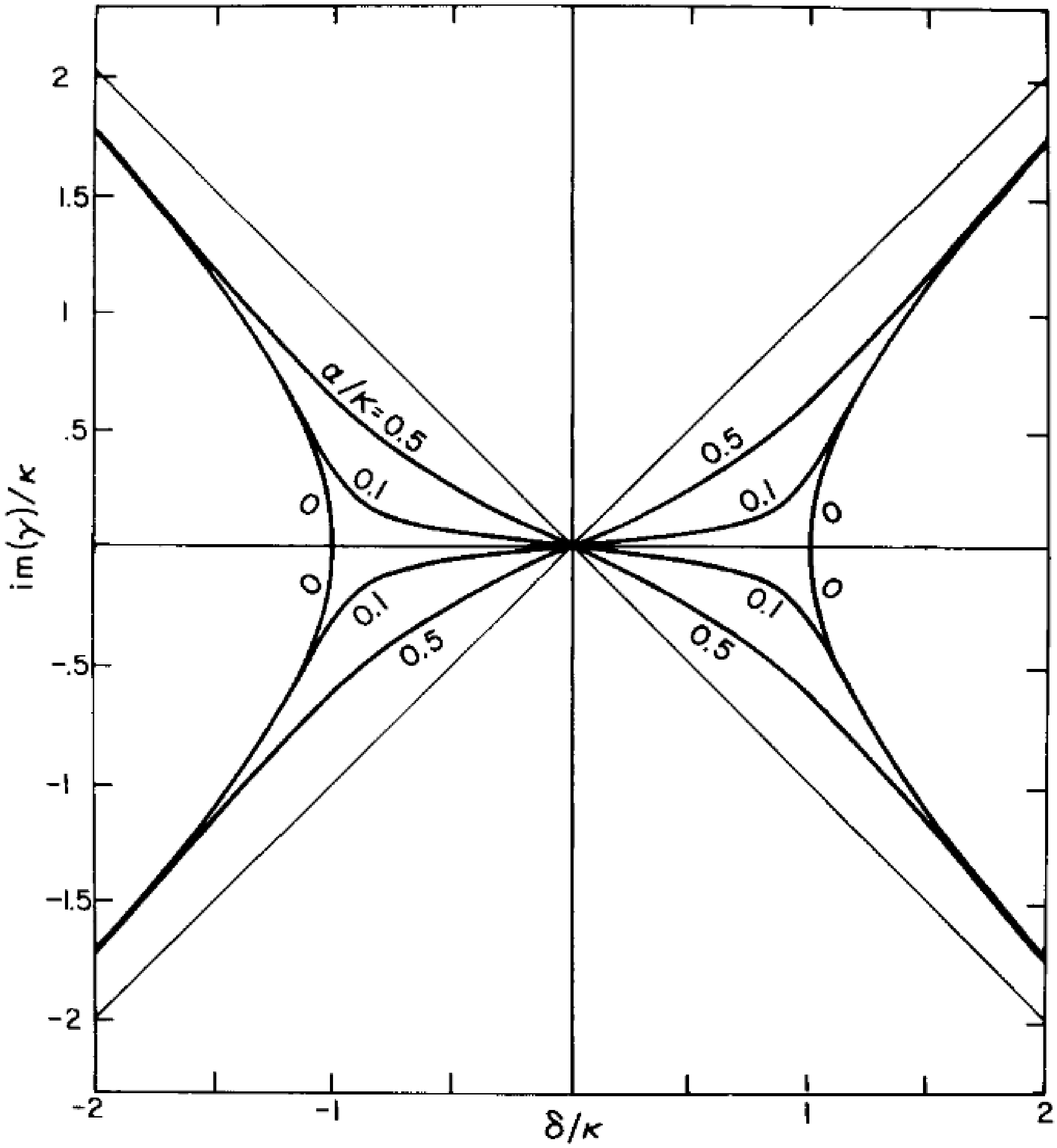


Fig. 1.2: Dispersion diagram for index modulation for various gain to coupling parameter ratios

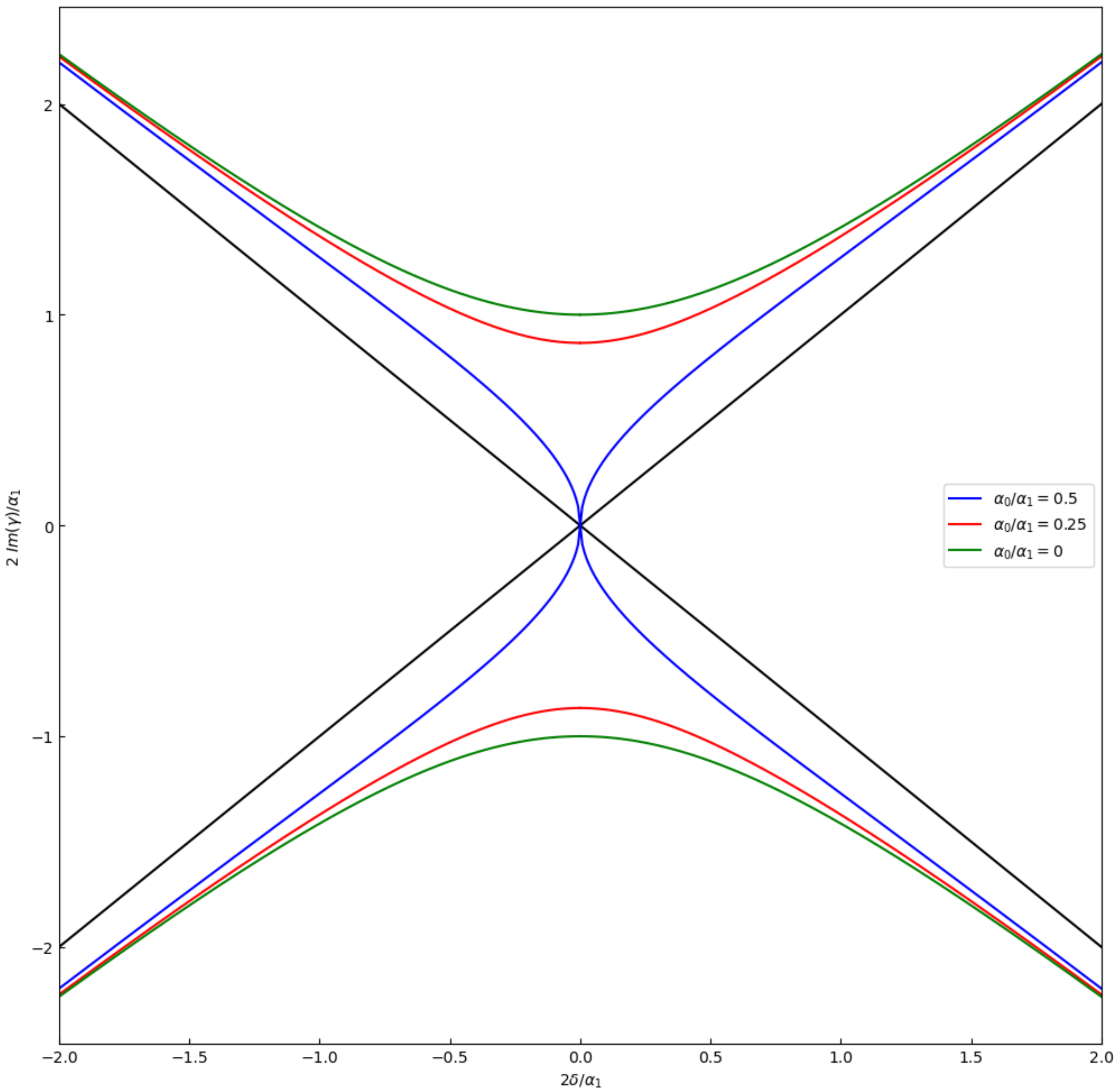


Fig. 1.3: Calculated dispersion diagram for gain modulation for various gain to coupling parameter ratios

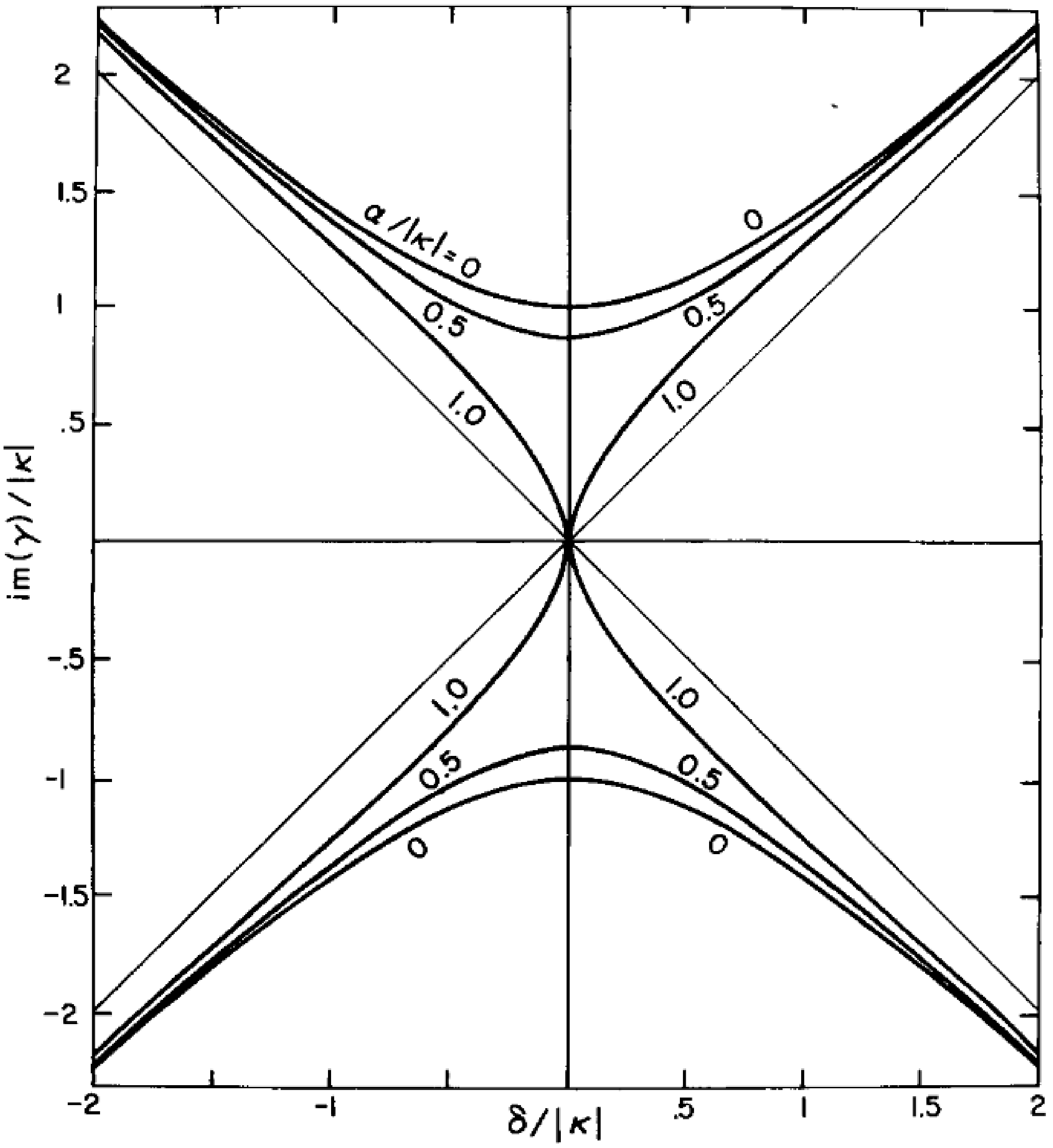


Fig. 1.4: Dispersion diagram for gain modulation for various gain to coupling parameter ratios

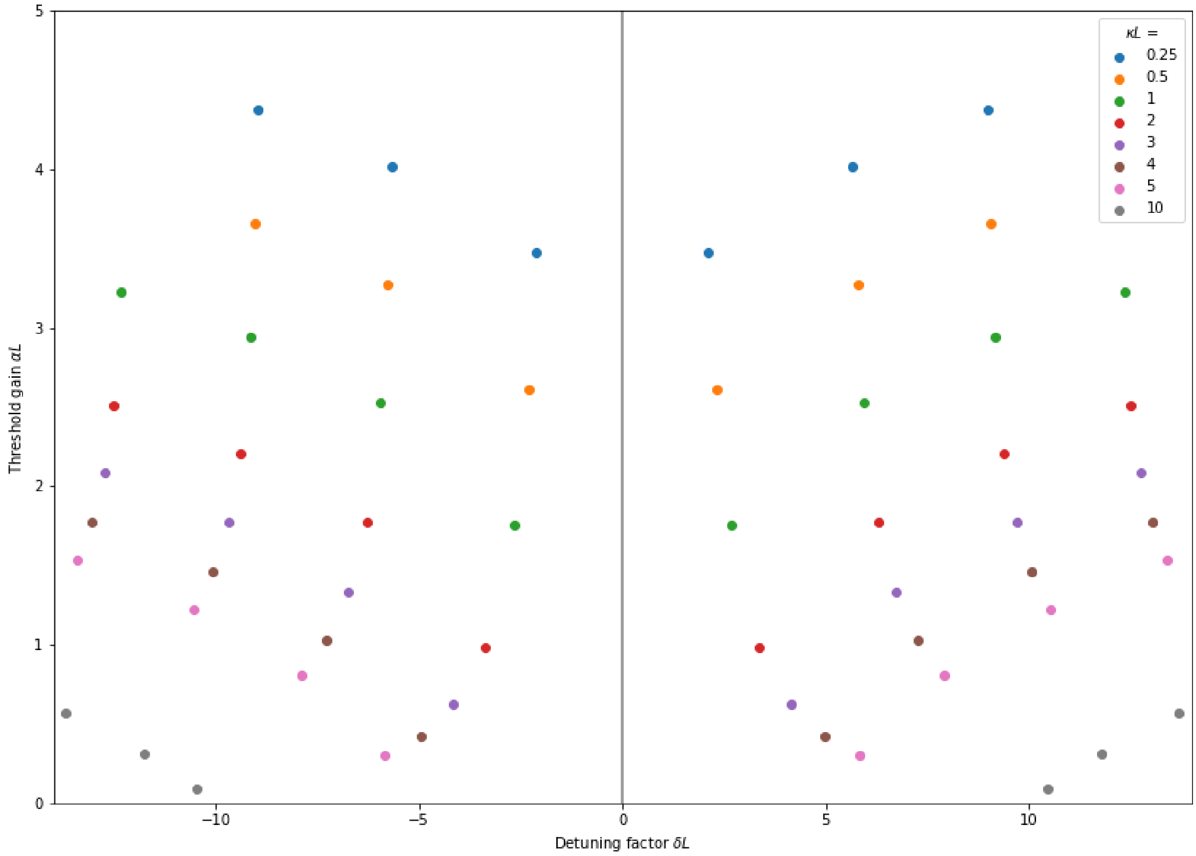


Fig. 1.5: Calculated gain required for threshold vs frequency deviation from the Bragg condition for index modulation

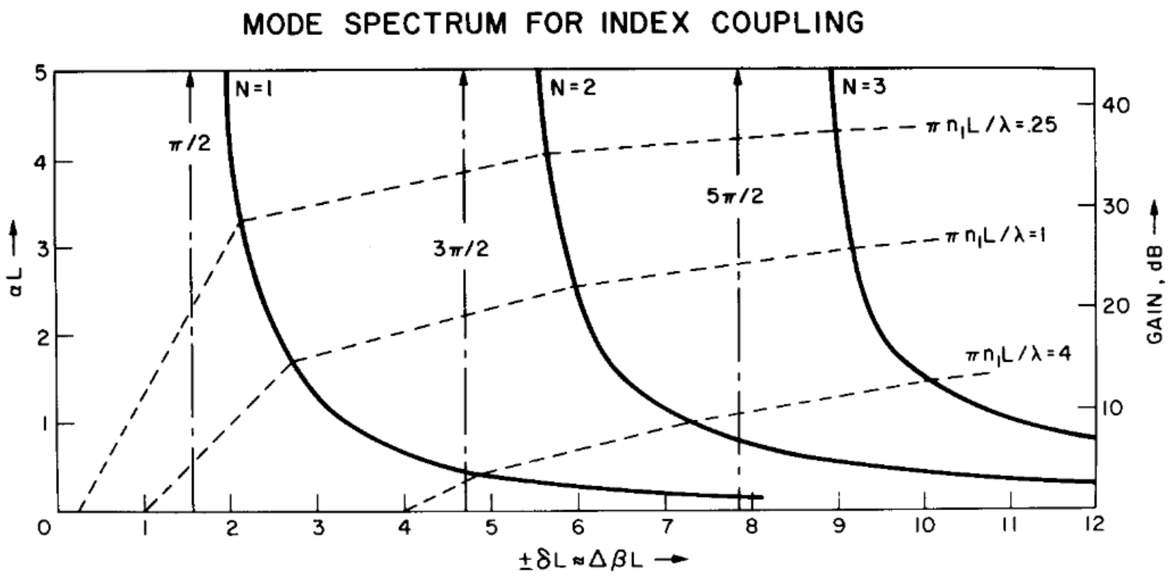


Fig. 1.6: Plot of the gain required for threshold vs frequency deviation from the Bragg condition for an index modulation. Only half of the spectrum is shown because of symmetry.

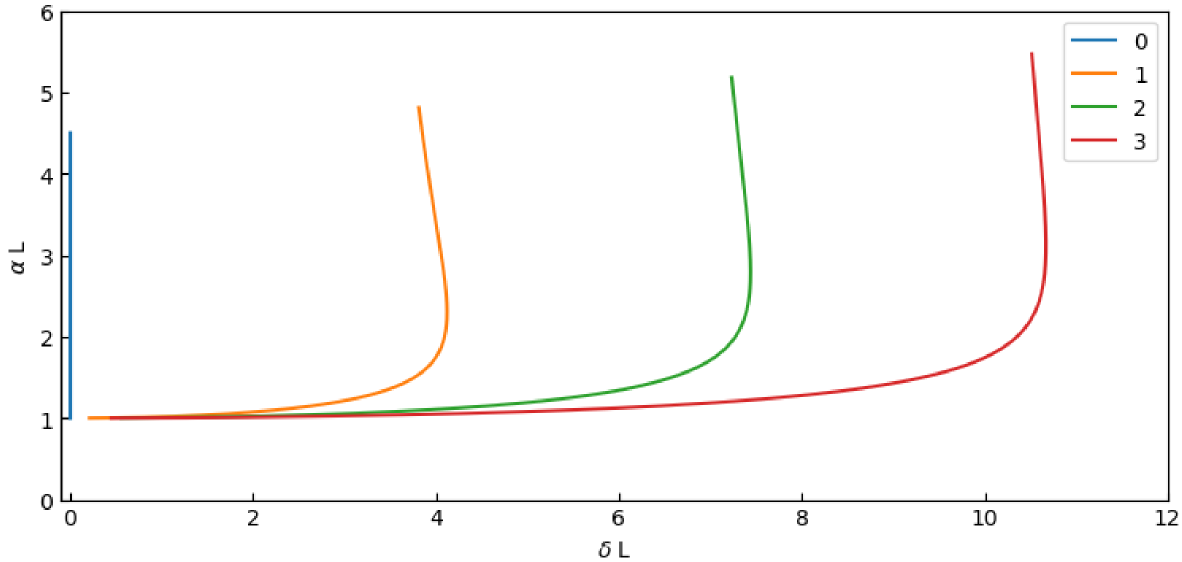


Fig. 1.7: Calculated DC gain required for threshold vs frequency deviation from the Bragg condition for gain modulation

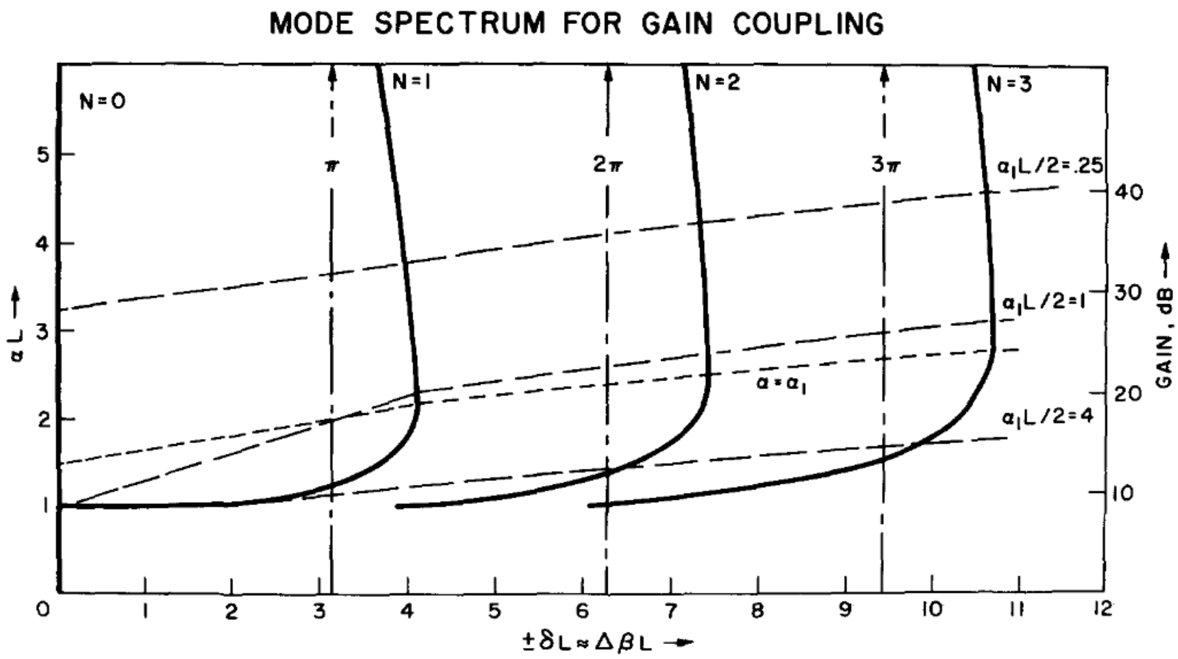


Fig. 1.8: Plot of the DC gain required for threshold vs frequency deviation from the Bragg condition for gain modulation. Only half of the spectrum is shown because of symmetry.

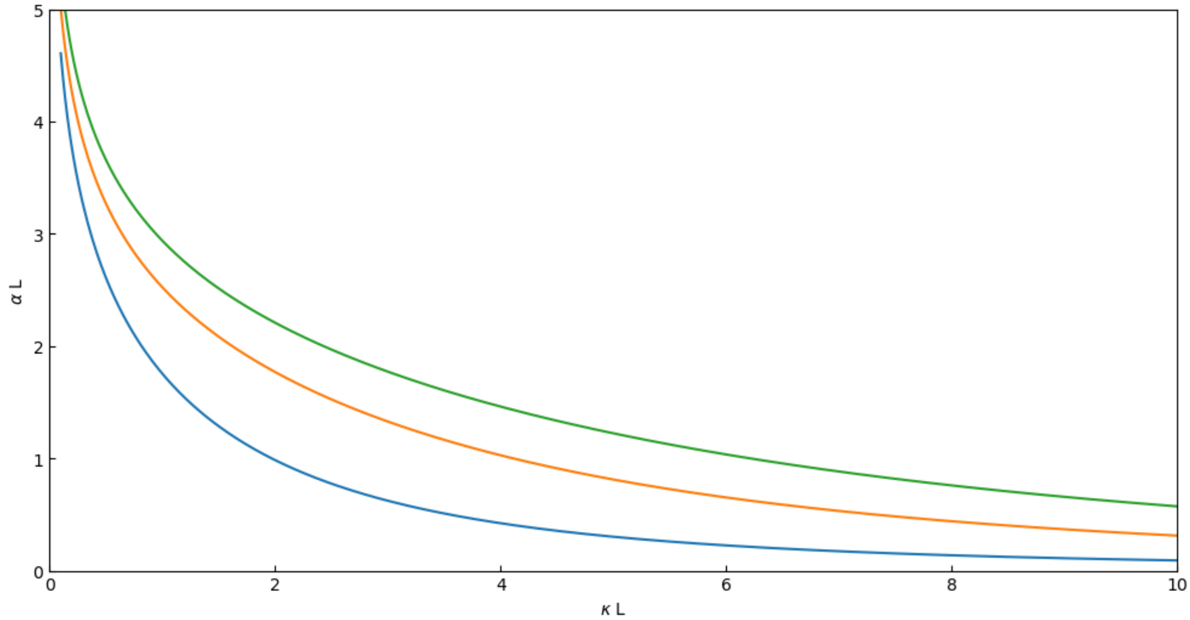


Fig. 1.9: Calculated gain at threshold vs coupling strength for various modes

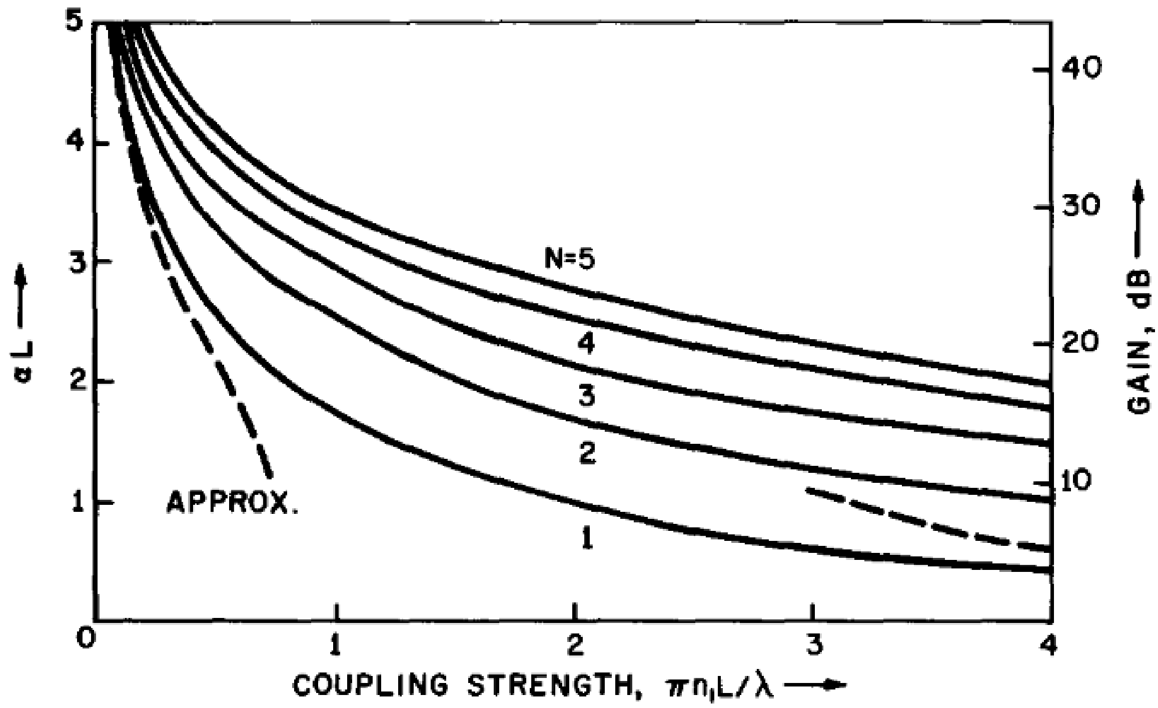


Fig. 1.10: Plot of the gain at threshold vs coupling strength for various modes. The mode number N refers to a set of modes placed symmetrically about the Bragg frequency.

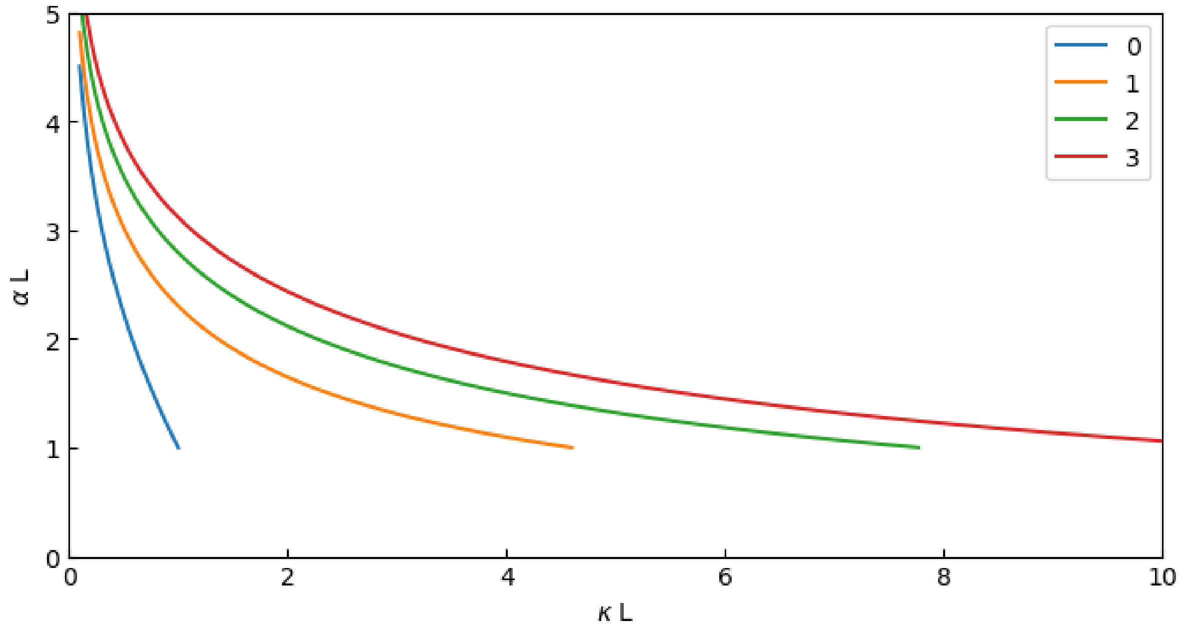


Fig. 1.11: Calculated gain at threshold vs coupling strength for various modes

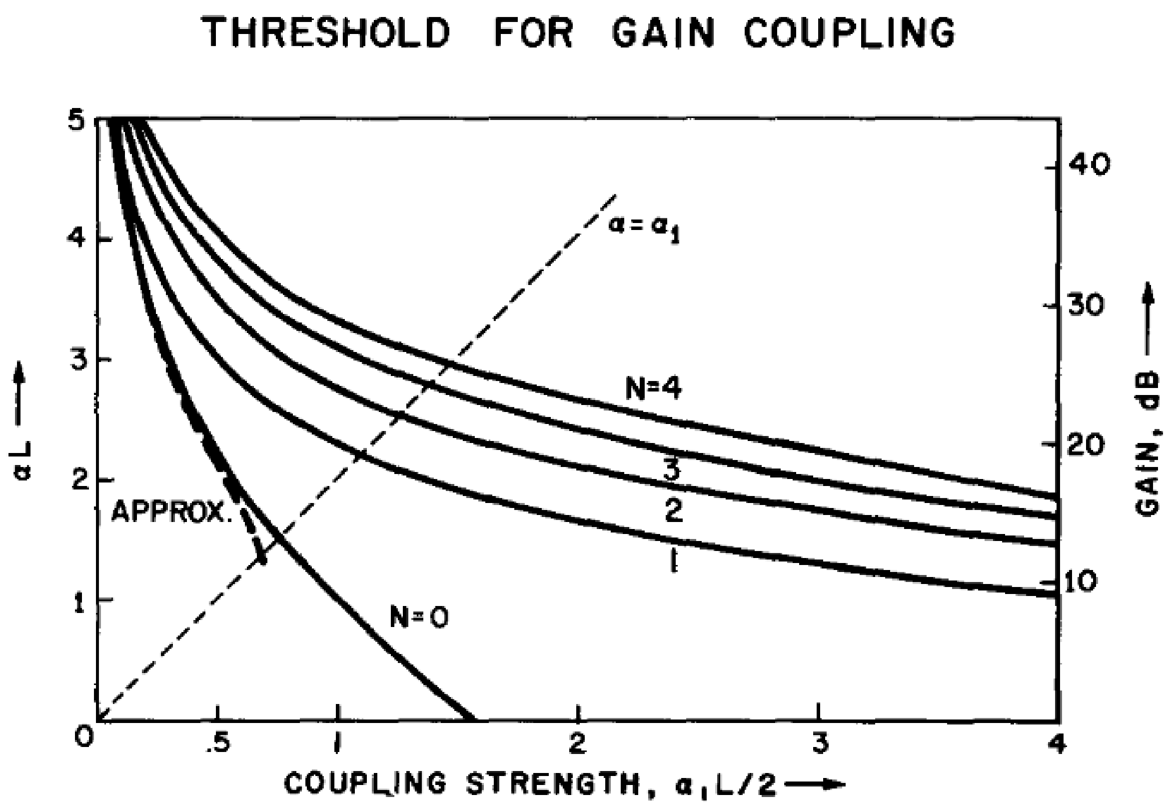


Fig. 1.12: Plot of the gain at threshold vs coupling strength for various modes. The N=O mode corresponds to a mode at the Bragg frequency. The numbers N>O correspond to a set of modes symmetrically placed about the Bragg frequency.

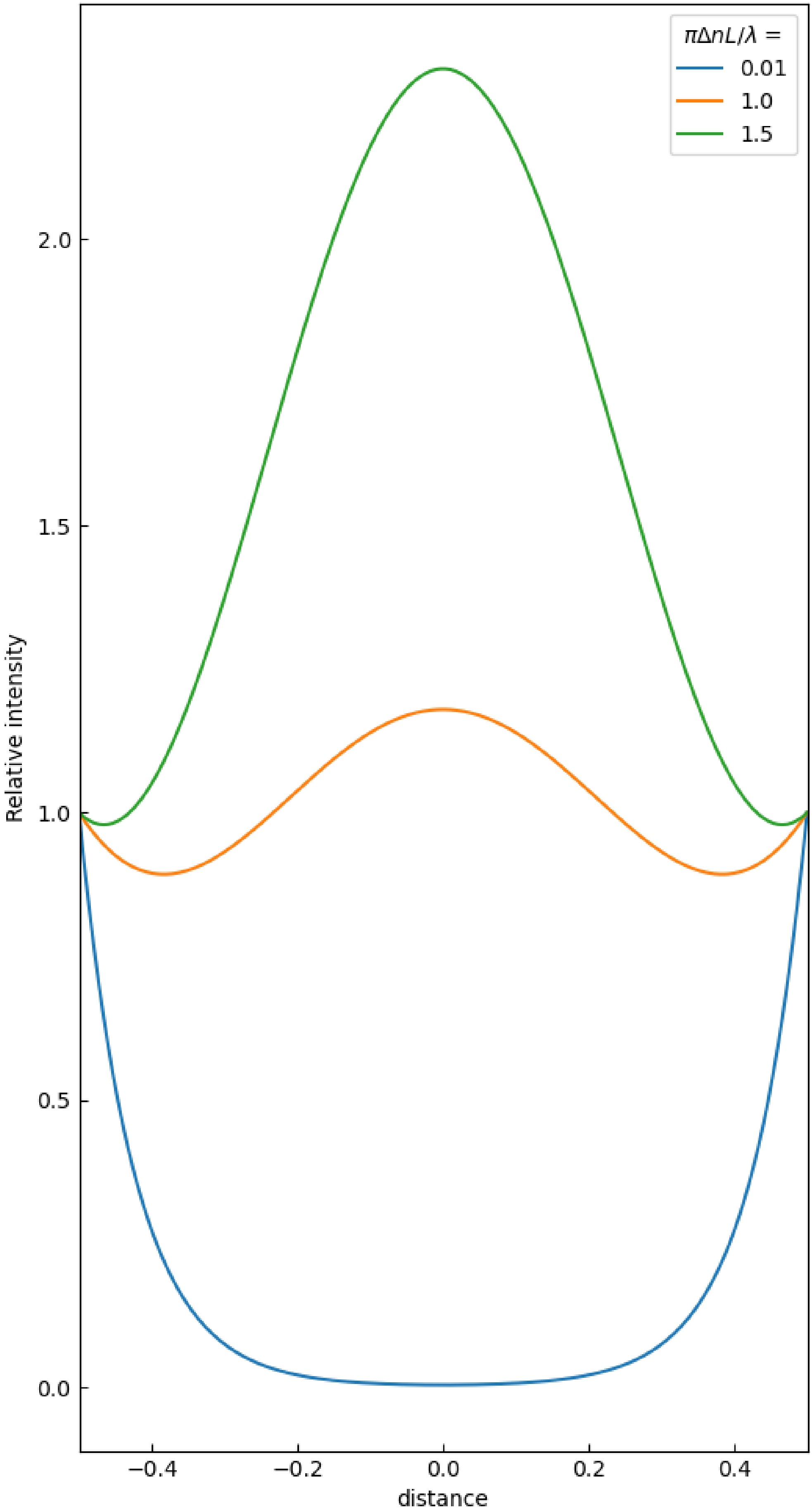


Fig. 1.13: Calculated gain at threshold vs coupling strength for various modes

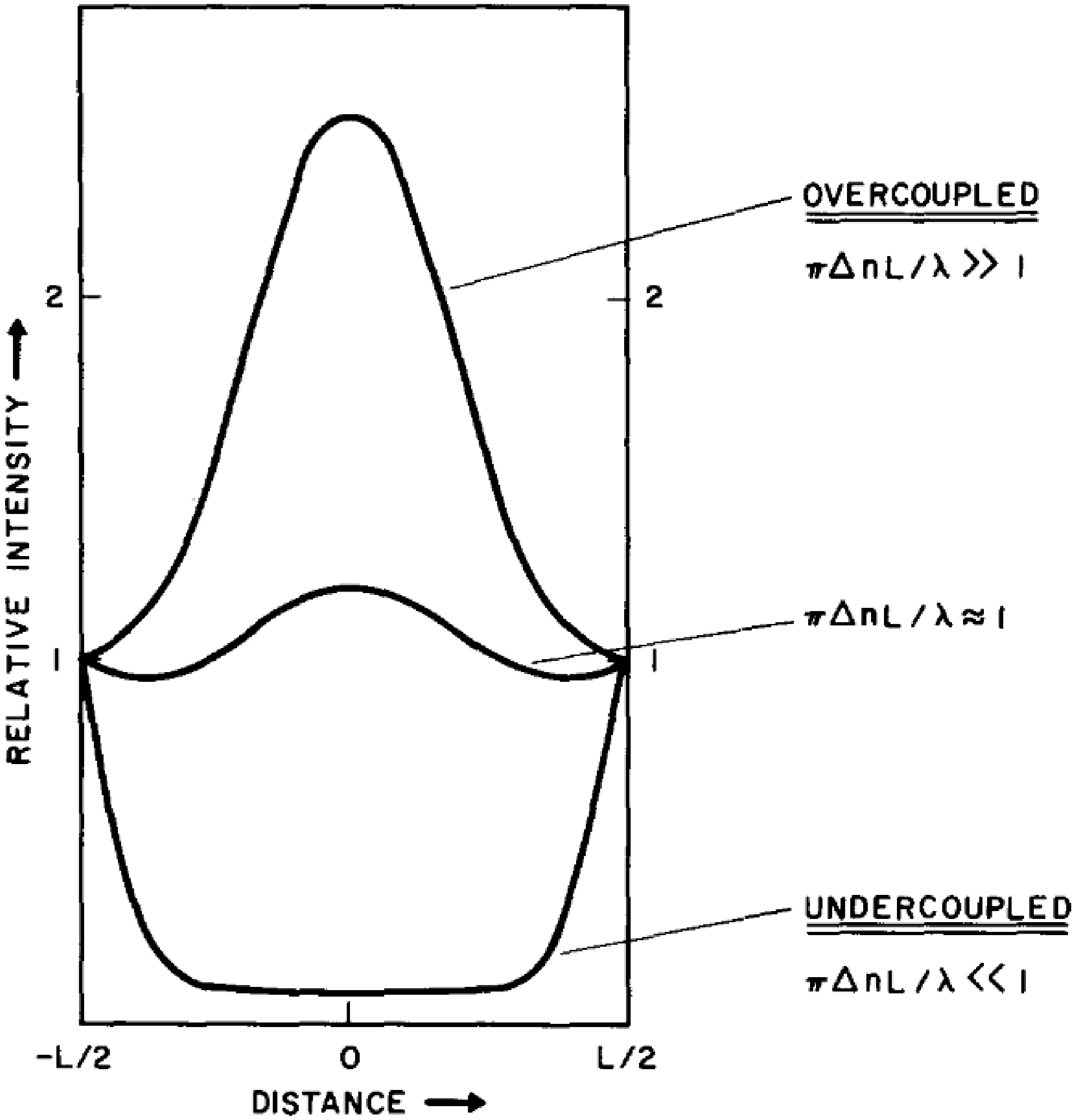


Fig. 1.14: Plot of the spatial intensity distribution of the lowest order modes at various coupling levels.

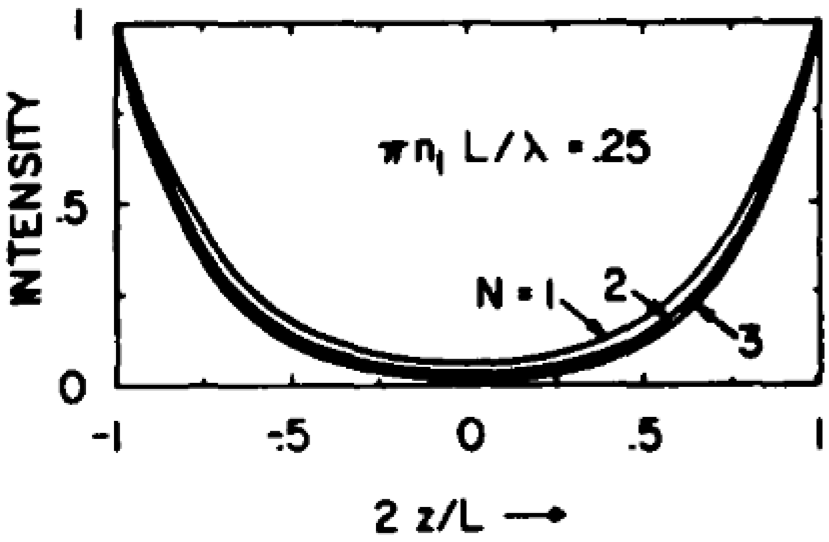


Fig. 1.15: Plot of the spatial intensity distribution for the first three modes at $\pi n_i L/\lambda = 0.25$.

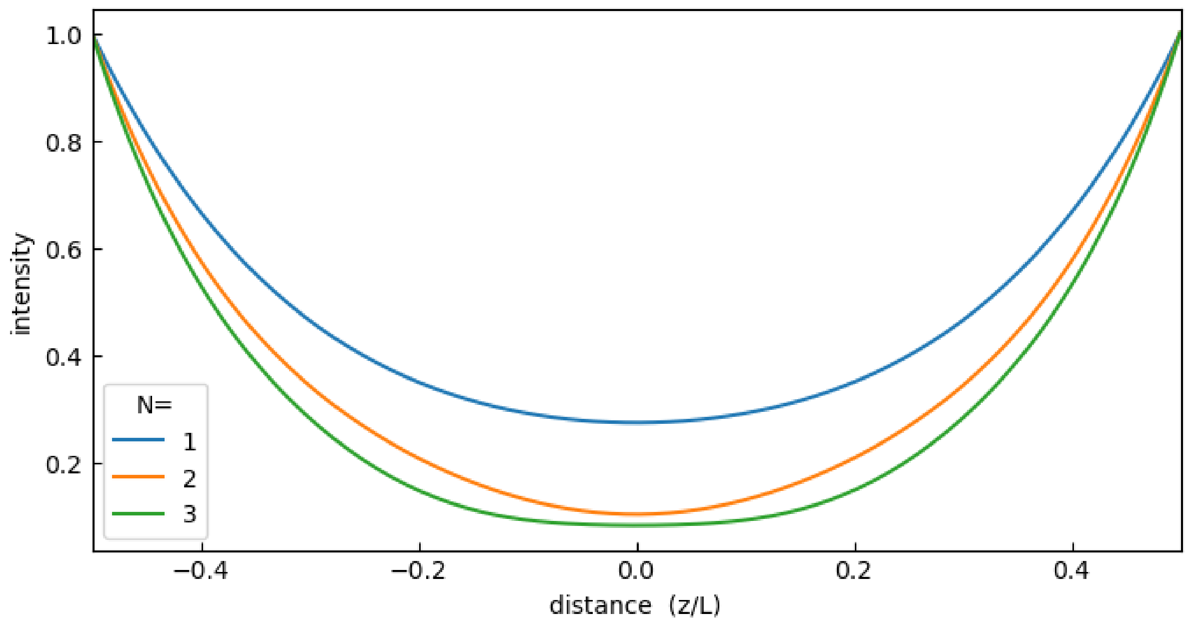


Fig. 1.16: Calculated spatial intensity distribution for the first three modes

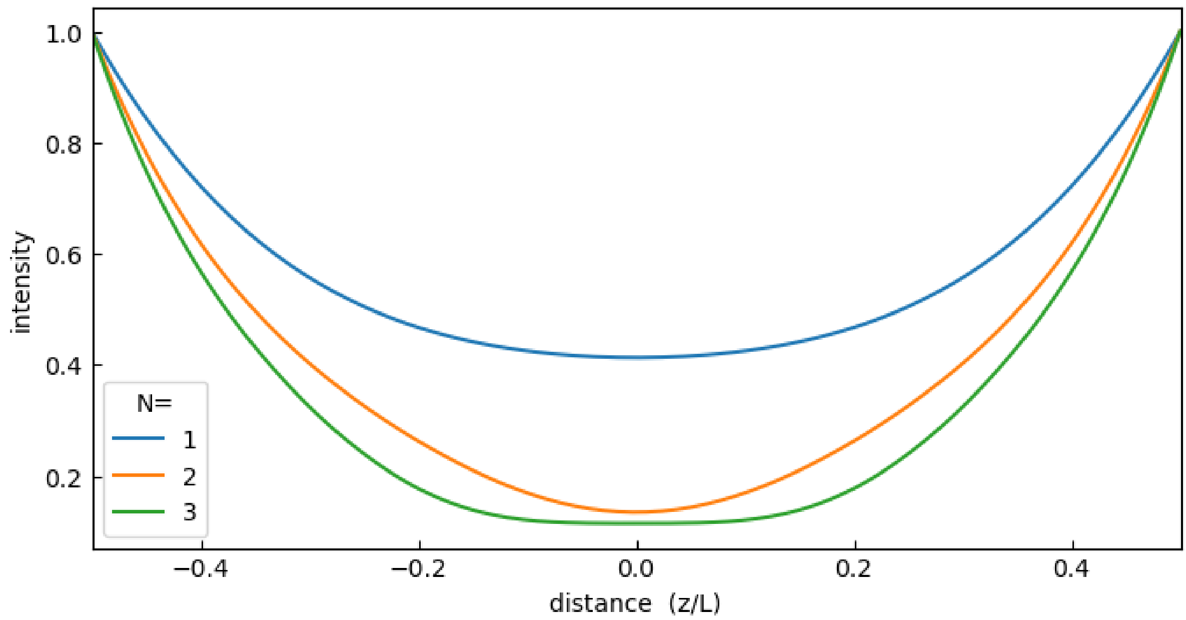


Fig. 1.17: Calculated spatial intensity distribution for the first three modes

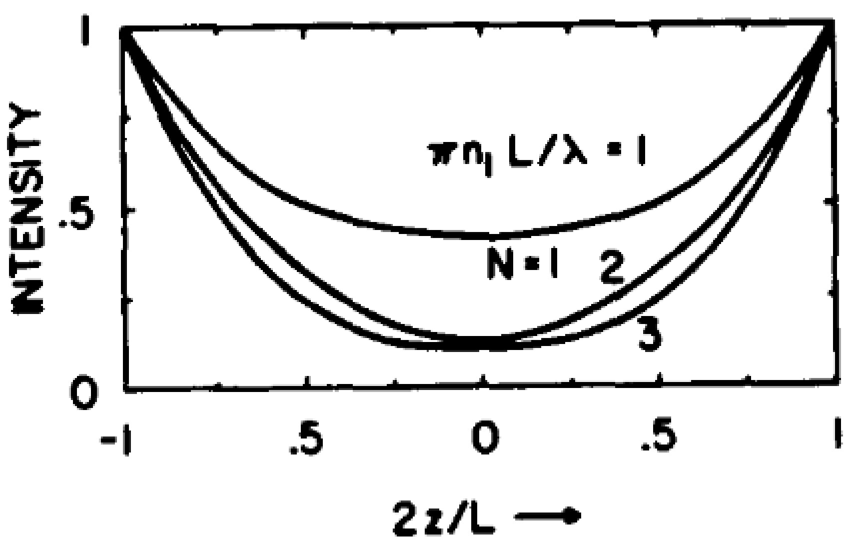


Fig. 1.18: Plot of the spatial intensity distribution for the first three modes at $\pi n_i L/\lambda = 1$.

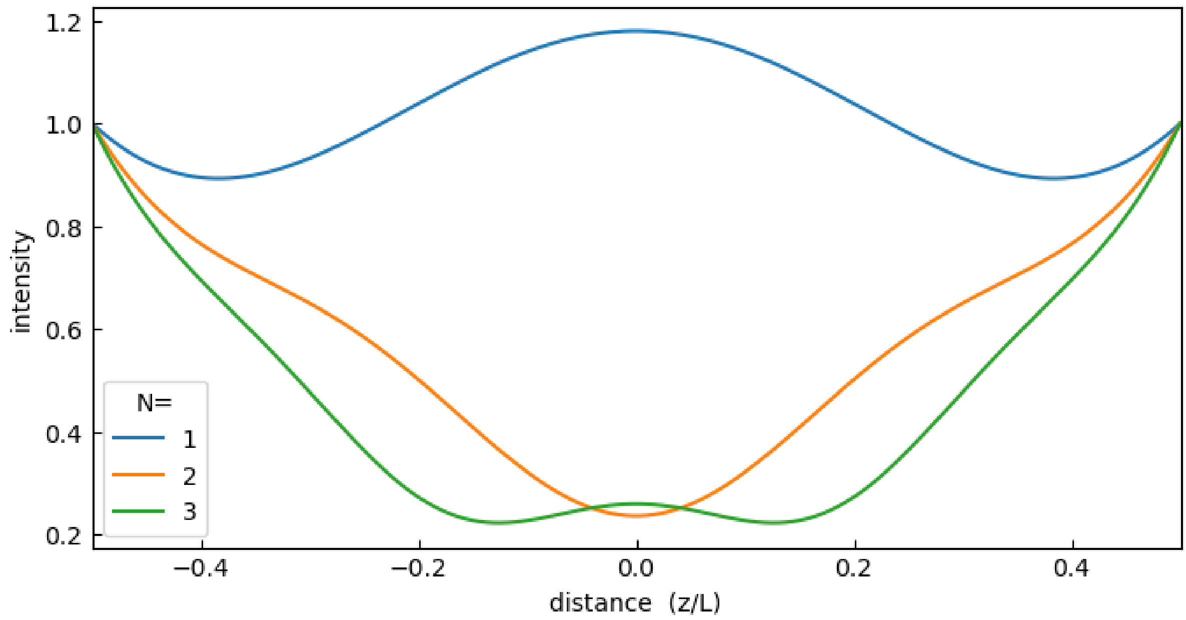


Fig. 1.19: Calculated spatial intensity distribution for the first three modes

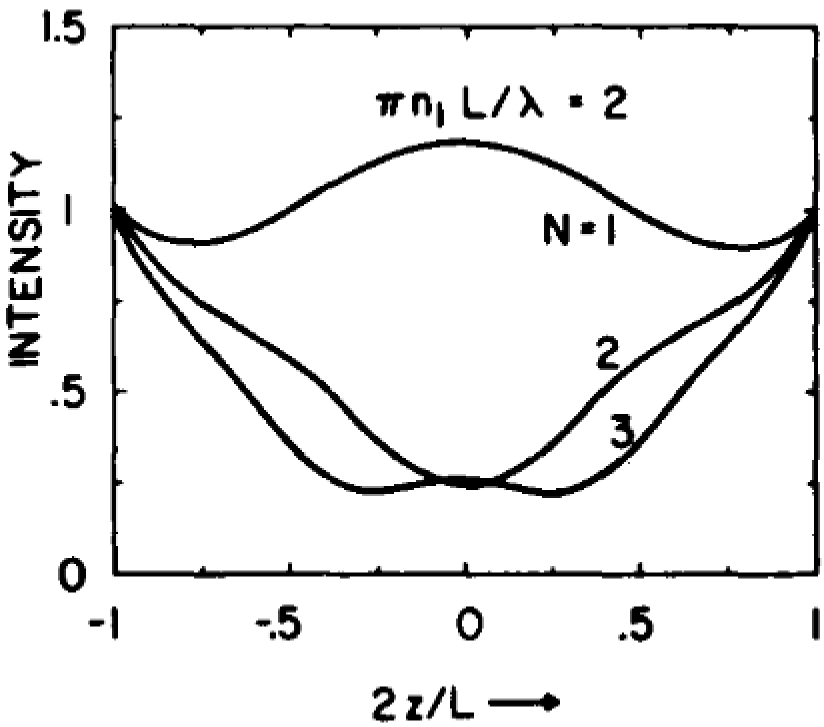


Fig. 1.20: Plot of the spatial intensity distribution for the first three modes at $\pi n_i L/\lambda = 2$.

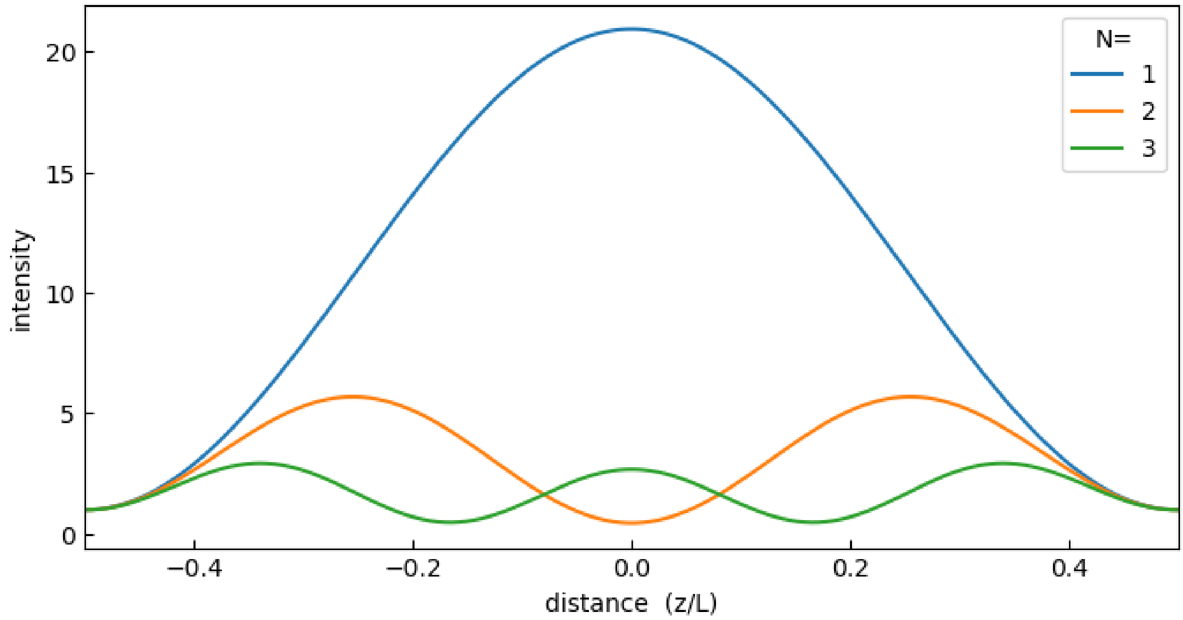


Fig. 1.21: Calculated spatial intensity distribution for the first three modes

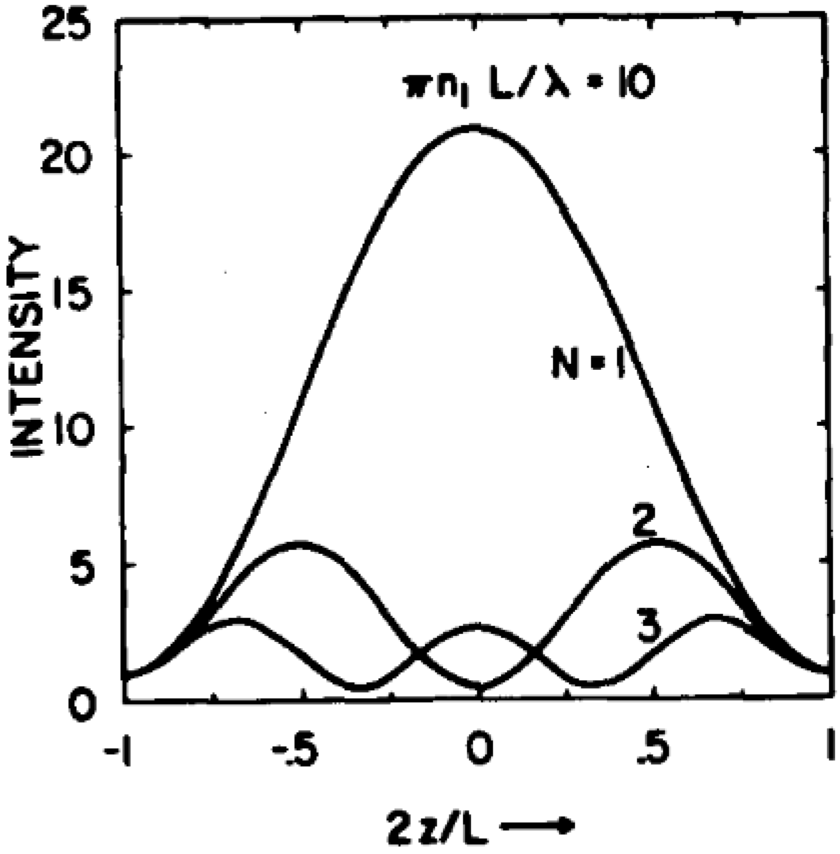


Fig. 1.22: Plot of the spatial intensity distribution for the first three modes at $\pi n_i L/\lambda = 10$.

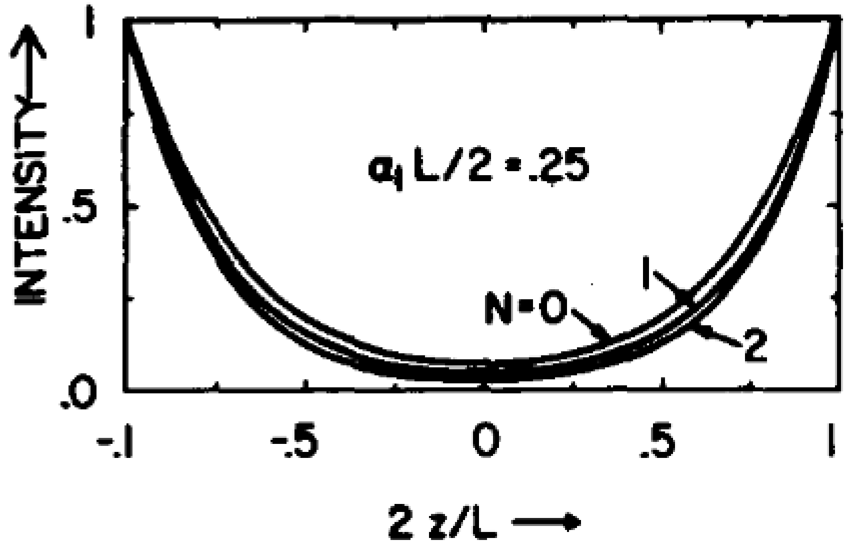


Fig. 1.23: Plot of the spatial intensity distribution for the first three modes at $\alpha L/2 = 0.25$.

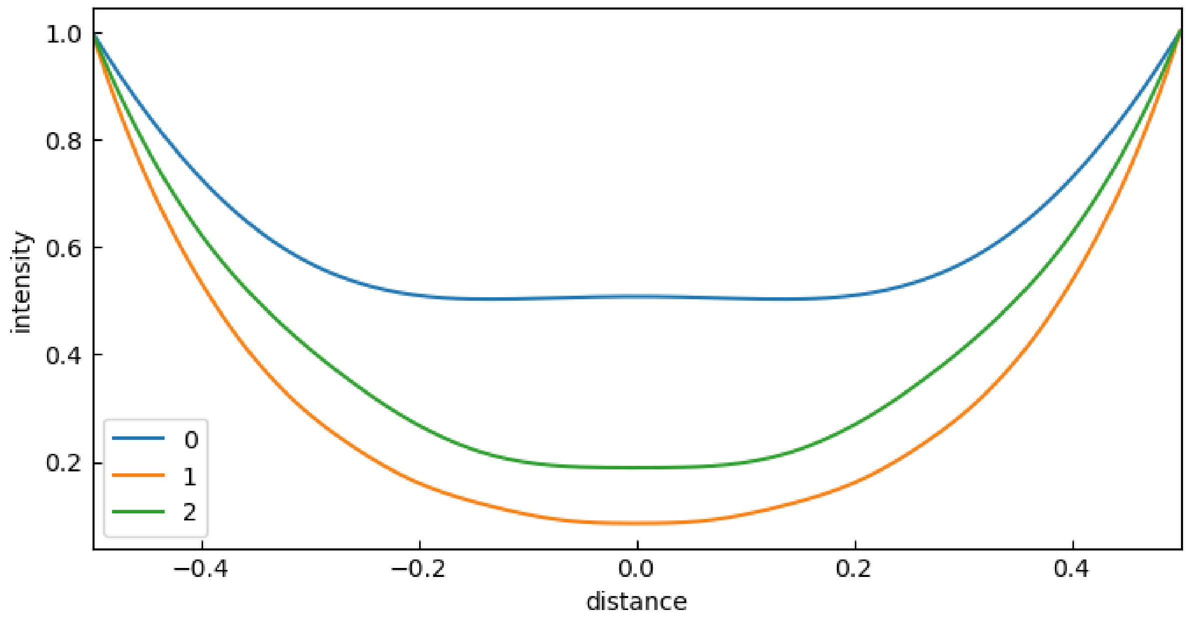


Fig. 1.24: Calculated spatial intensity distribution for the first three modes at L / 2 =1

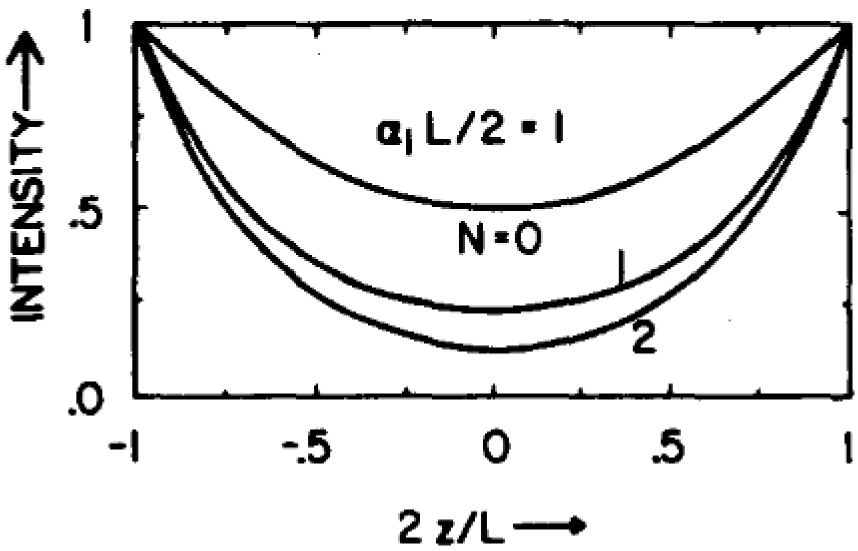


Fig. 1.25: Plot of the spatial intensity distribution for the first three modes at $\alpha L/2 = 1$.

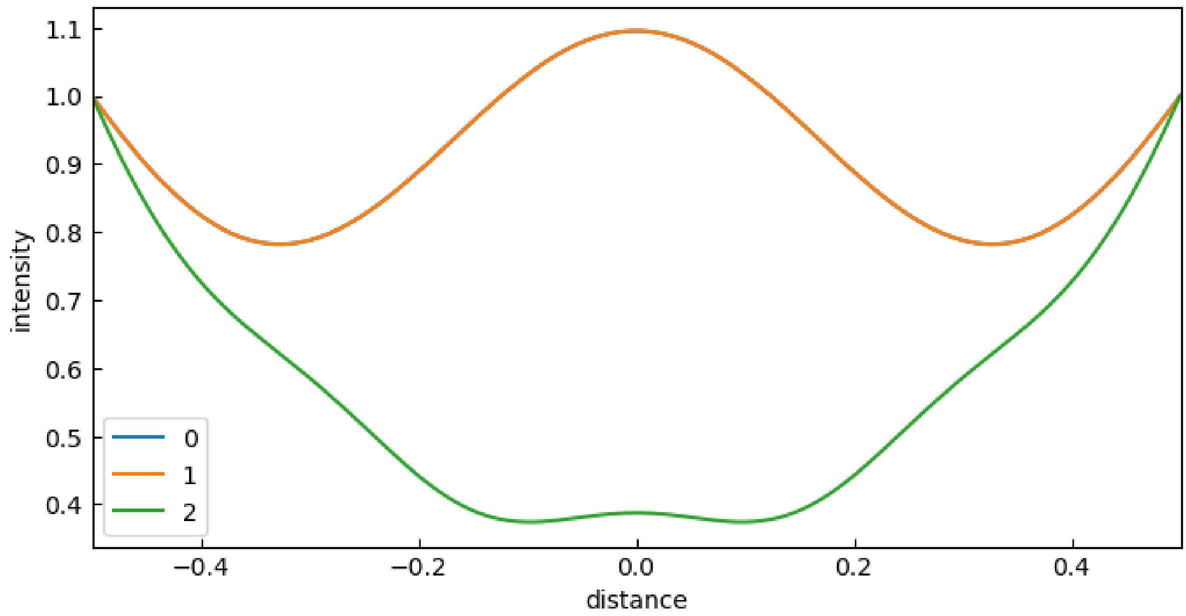


Fig. 1.26: Calculated spatial intensity distribution for the first three modes at L / 2 =2

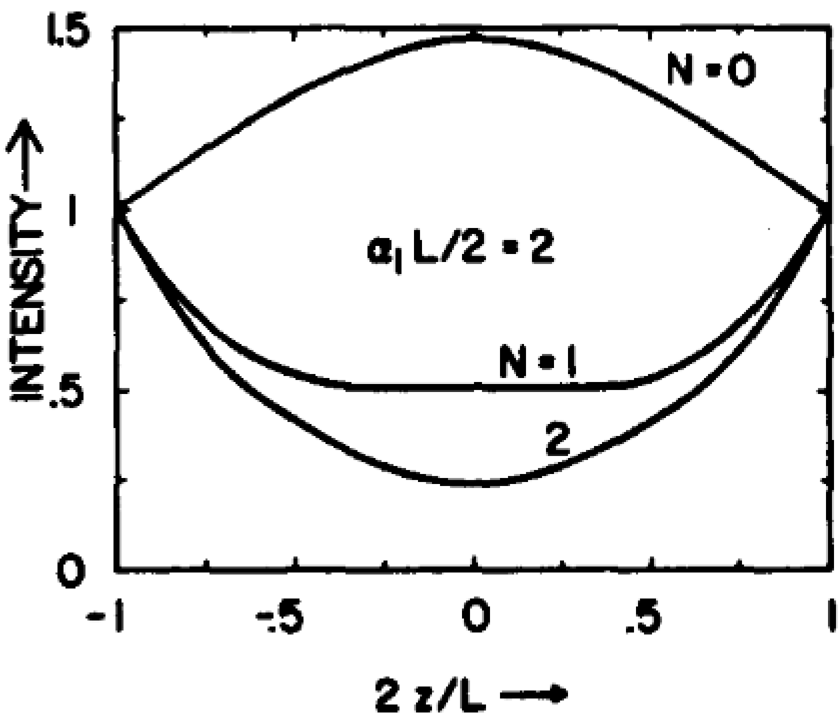


Fig. 1.27: Plot of the spatial intensity distribution for the first three modes at $\alpha L/2 = 2$.

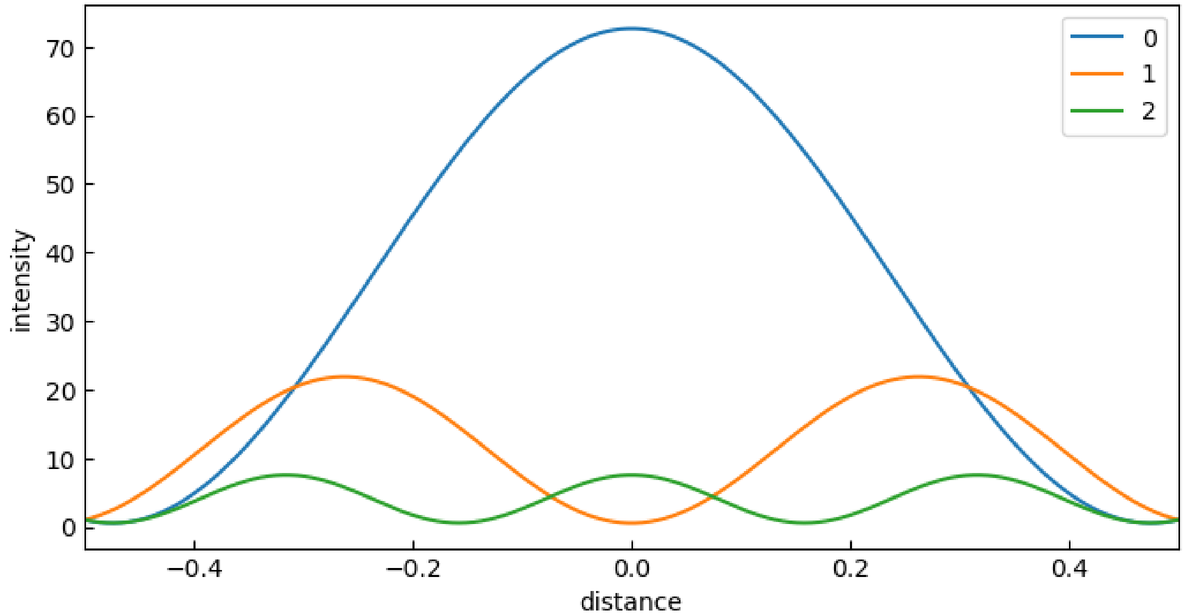


Fig. 1.28: Calculated spatial intensity distribution for the first three modes at L / 2 =10

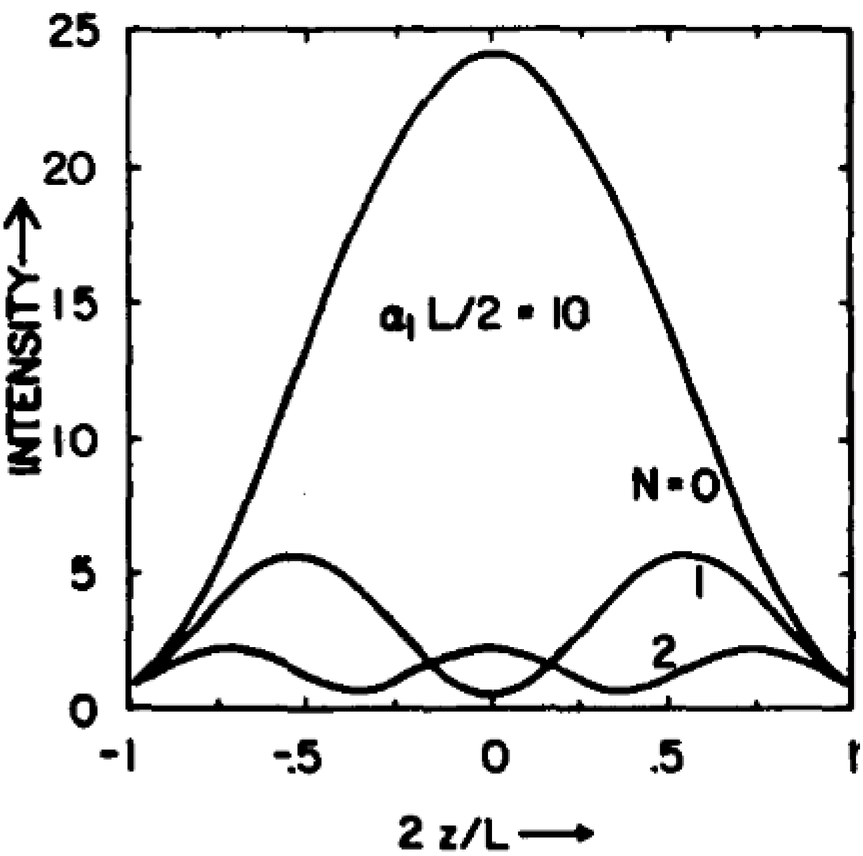


Fig. 1.29: Plot of the spatial intensity distribution for the first three modes at $\alpha L/2 = 10$.

CHAPTER

# TWO

# UV-NANOIMPRINTED DISTRIBUTED-FEEDBACK PEROVSKITE LASING

This chapter comprises simulations from the manuscript:

Iakov Goldberg, Nirav Annavarapu, Simon Leitner, Karim Elkhouly, Fei Han, Tibor Kuna, Weiming Qiu, Cedric Rolin, Jan Genoe, Robert Gehlhaar and Paul Heremans, *"Multimode Lasing in All-Solution-Processed UV-Nanoimprinted Distributed Feedback MAPbI$_3$ Perovskite Waveguides"*, submitted manuscript

The calculation of the modes is done in accordance to [1].

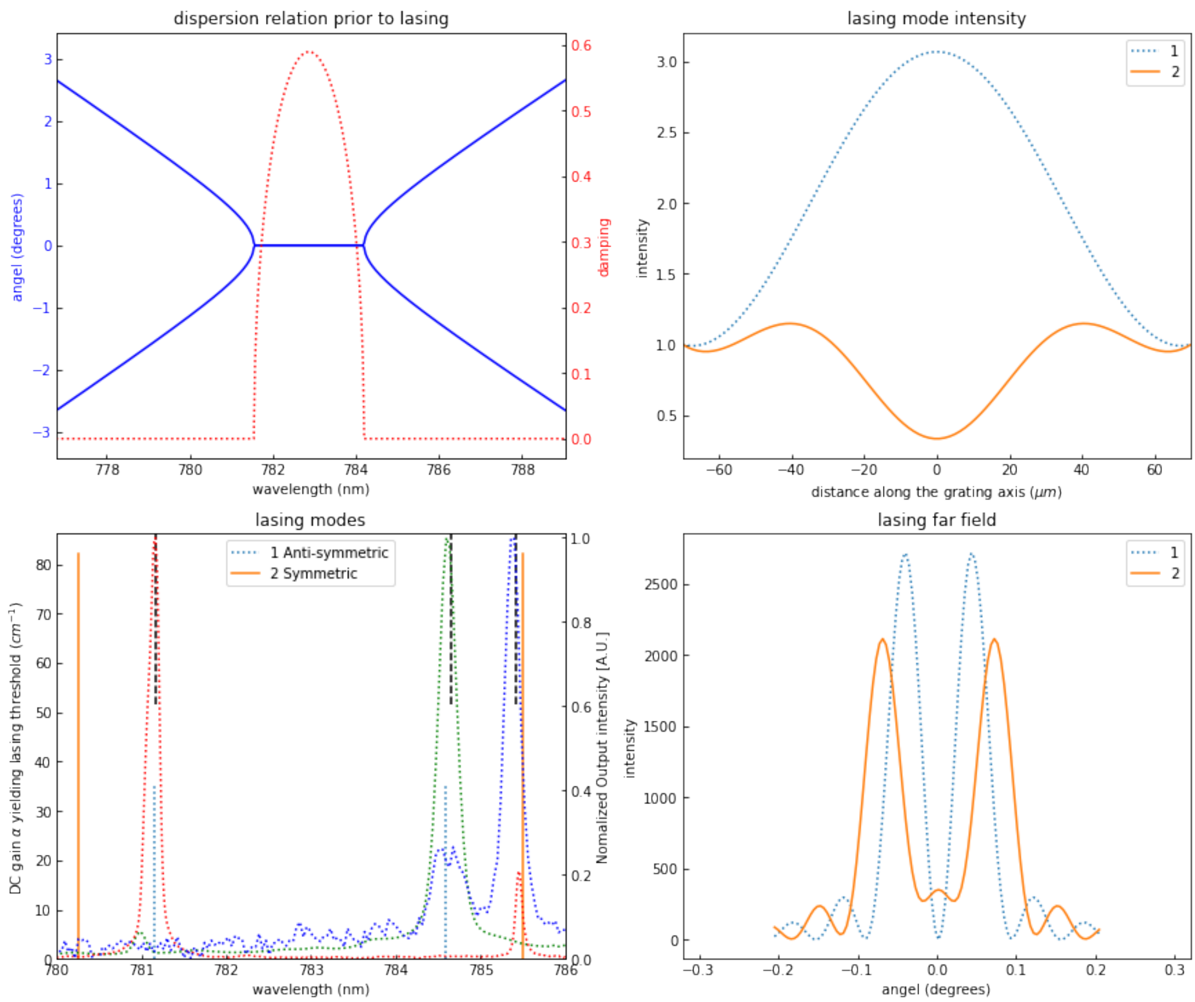


Fig. 2.1: Upper left: calculated dispersion relation prior to lasing, Upper right: intensity of the lasing mode in the near field, lower left: required DC gain for the lasing threshold, the dotted lines show the measured lasing lines at 3 different locations, lower right: far field lasing intensity as a function of the angle

CHAPTER

# THREE

# REFERENCES

# BIBLIOGRAPHY

[1] H. Kogelnik and C. V. Shank. Coupled-Wave Theory of Distributed Feedback Lasers. *Journal of Applied Physics*, 43(5):2327–2335, May 1972. doi:10.1063/1.1661499.