Improvement of the beam quality of a broad-area diode laser using asymmetric feedback from external cavity

Lei Lang, Jun Jun Lim, Slawomir Sujecki, Eric Larkins

Photonic and Radio Frequency Engineering Group

School of Electrical and Electronic Engineering

University of Nottingham, Nottingham NG7 2RD

Acknowledgements

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Presentation Outline

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1. Introduction
2. Description of External Cavity Laser Model
3. Results
4. Conclusion

Asymmetric Feedback from an External Cavity

- Asymmetric Feedback technique is also called self-injection locking (SIL). This is attractive because no additional laser processing is required.
- A mirror stripe is placed inside of the external cavity to select one of the lateral modes. This increases the modal discrimination with respect to the other modes.
- This cavity is optimized by adjusting the width and position of the mirror stripe.

Introduction

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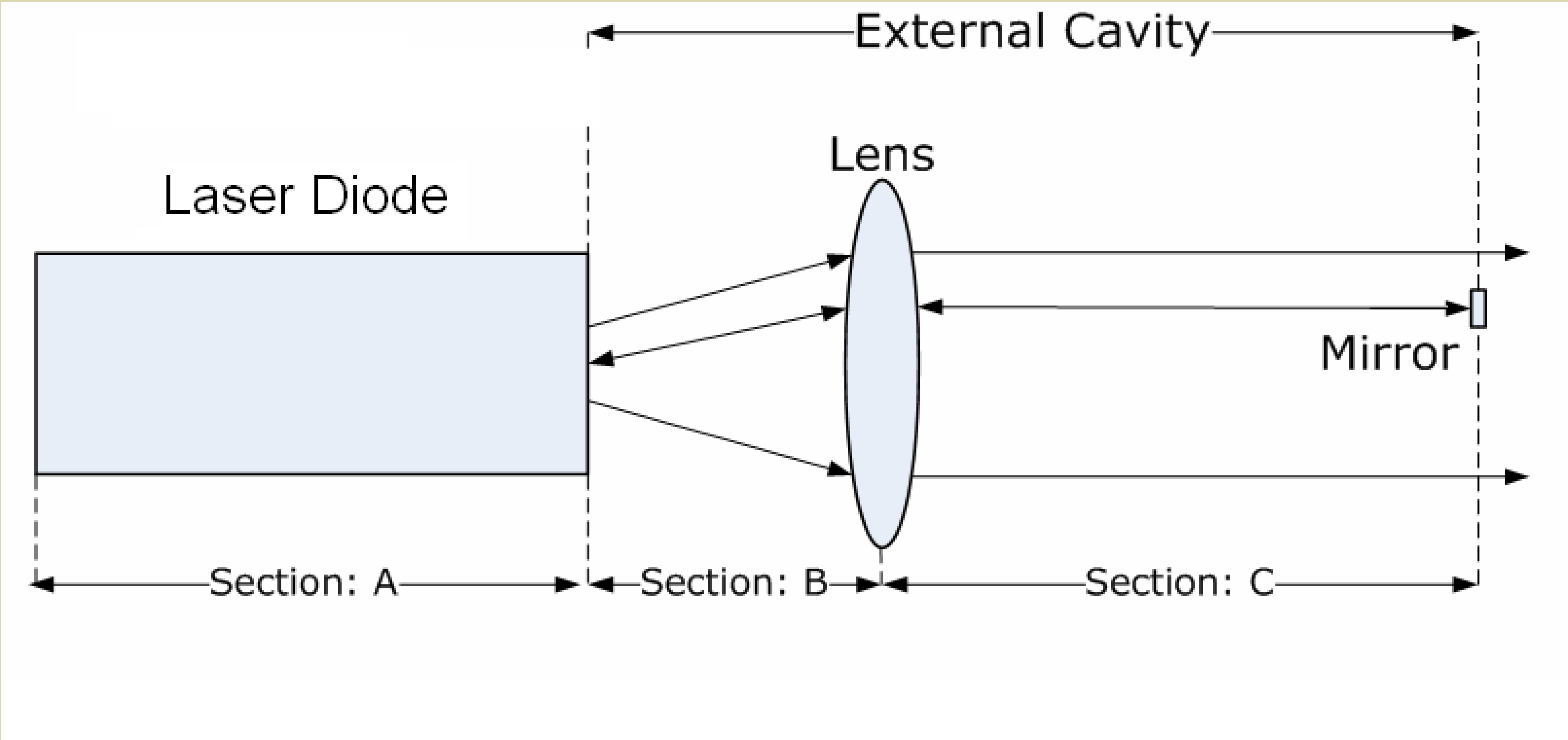
Physical Layout for Simulation



The broad-area laser diode model is coupled with a free space propagation model to build up the whole simulation structure.

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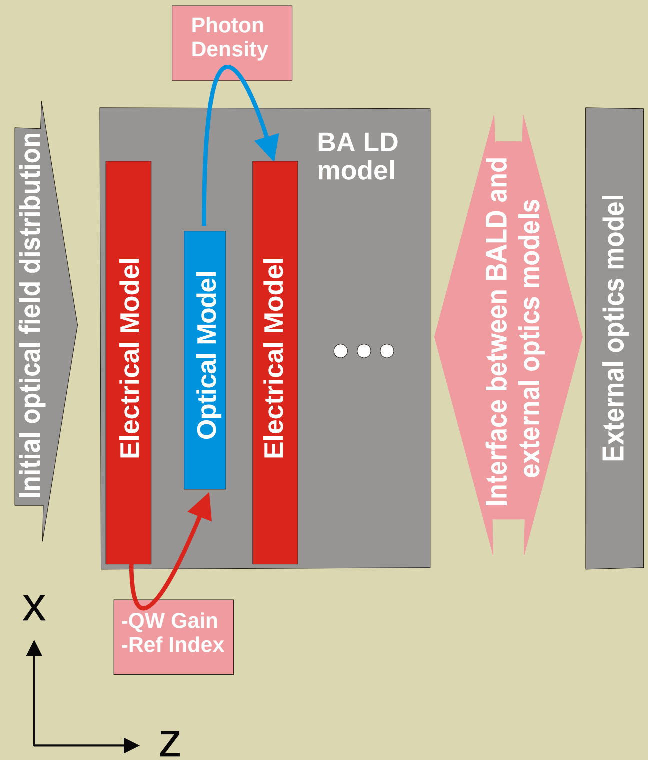
Broad Area Laser Diode Model

- **Electrical slice model - 1D (x) unipolar carrier-diffusion equation:**

$$D_e \frac{d^2}{dx^2} N(x) = -\frac{J(x)}{qd} + \frac{N(x)}{\tau_n} + v_g g(x) \Psi(x) N_s$$

- ***J(x)* is assumed fixed**
  - **Constant inside stripe**
  - **Zero outside stripe**
- **Gain calculated using parabolic approximation for conduction bands and 4x4 k.p model for valence bands.**
- **Optical model - 2D (xz) wide-angle FD-BPM with PML**



External Cavity Model

- **The external optics model uses the Fourier Transform (FT) Method.**

Initial input field FT:

$$A(\frac{\alpha}{\lambda},0)=\int_{-\infty}^{\infty}U(x,0)\exp(-j2\pi\frac{\alpha}{\lambda}x)dx$$

Propagation towards z direction

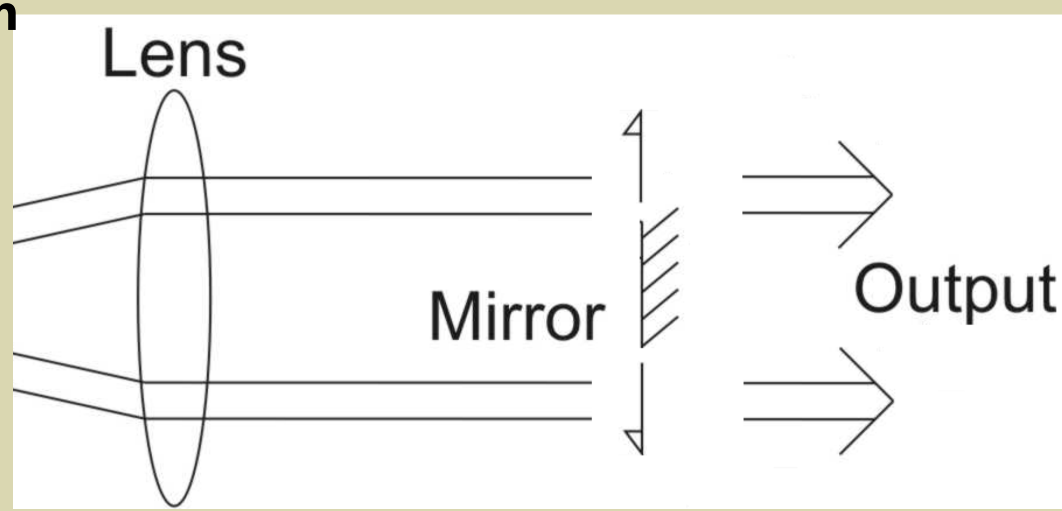
$$A(\frac{\alpha}{\lambda},z)=A(\frac{\alpha}{\lambda},0)\exp(j\frac{2\pi}{\lambda}\sqrt{1-\alpha^2}z)$$

Spatial domain format by using

Inverse FT:

$$U(x,z)=\int_{-\infty}^{\infty}A(\frac{\alpha}{\lambda},z)\exp(j2\pi\frac{\alpha}{\lambda}x)d\frac{\alpha}{\lambda}$$

External optics model



Focal length = 63 mm

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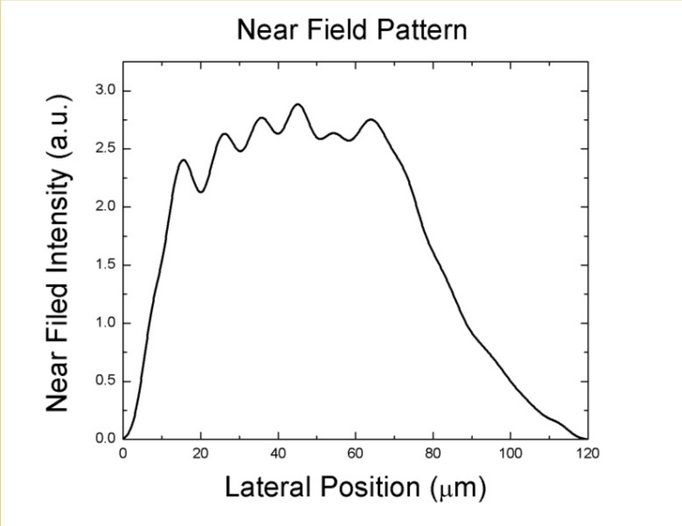
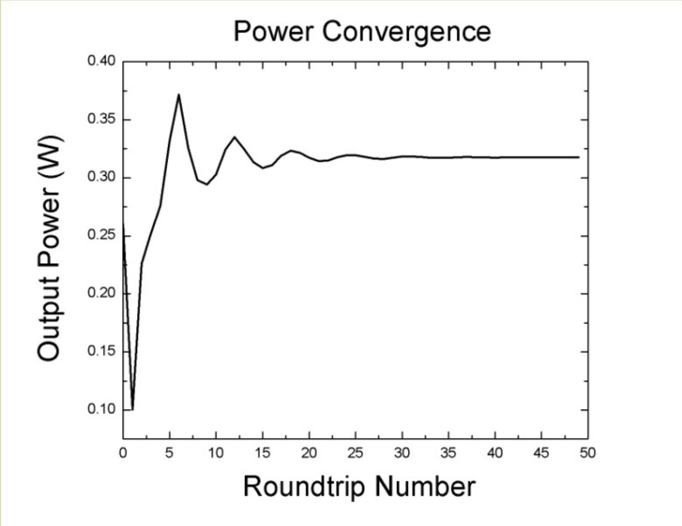
Results

- BA laser: W = 100 μm, L = 1 mm
- Initial field – "top hat profile"
- Simulation converges for a specific reflector width and position
  - Reflector width = 0.74 mm
  - Position of reflector = 2.97 mm from centre

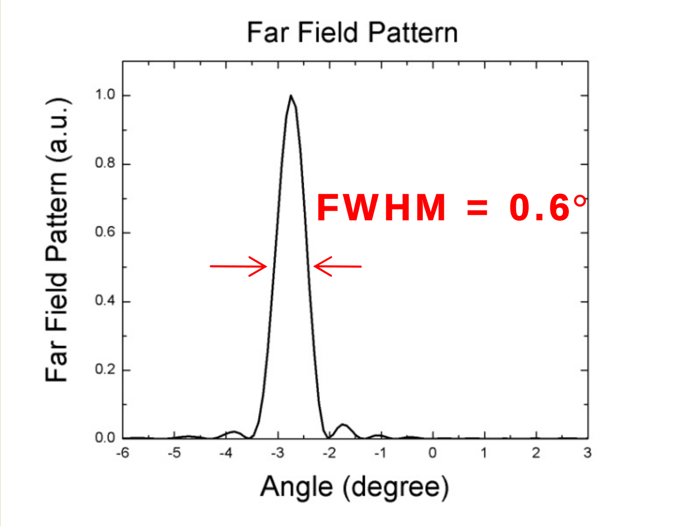
Near field profile



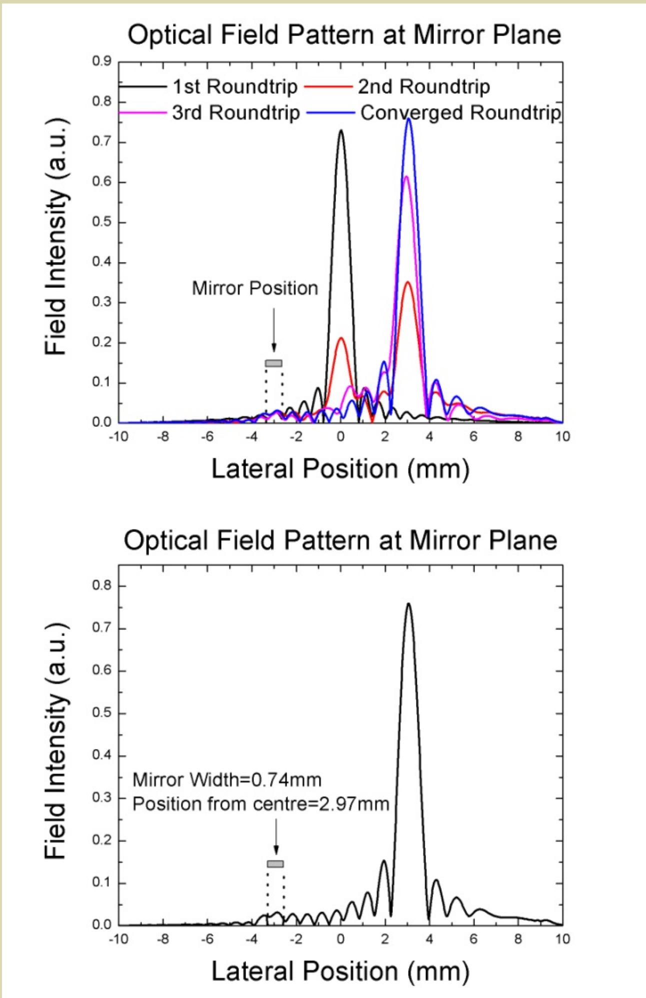
Power vs. Roundtrip



Far field profile



Mirror position and width

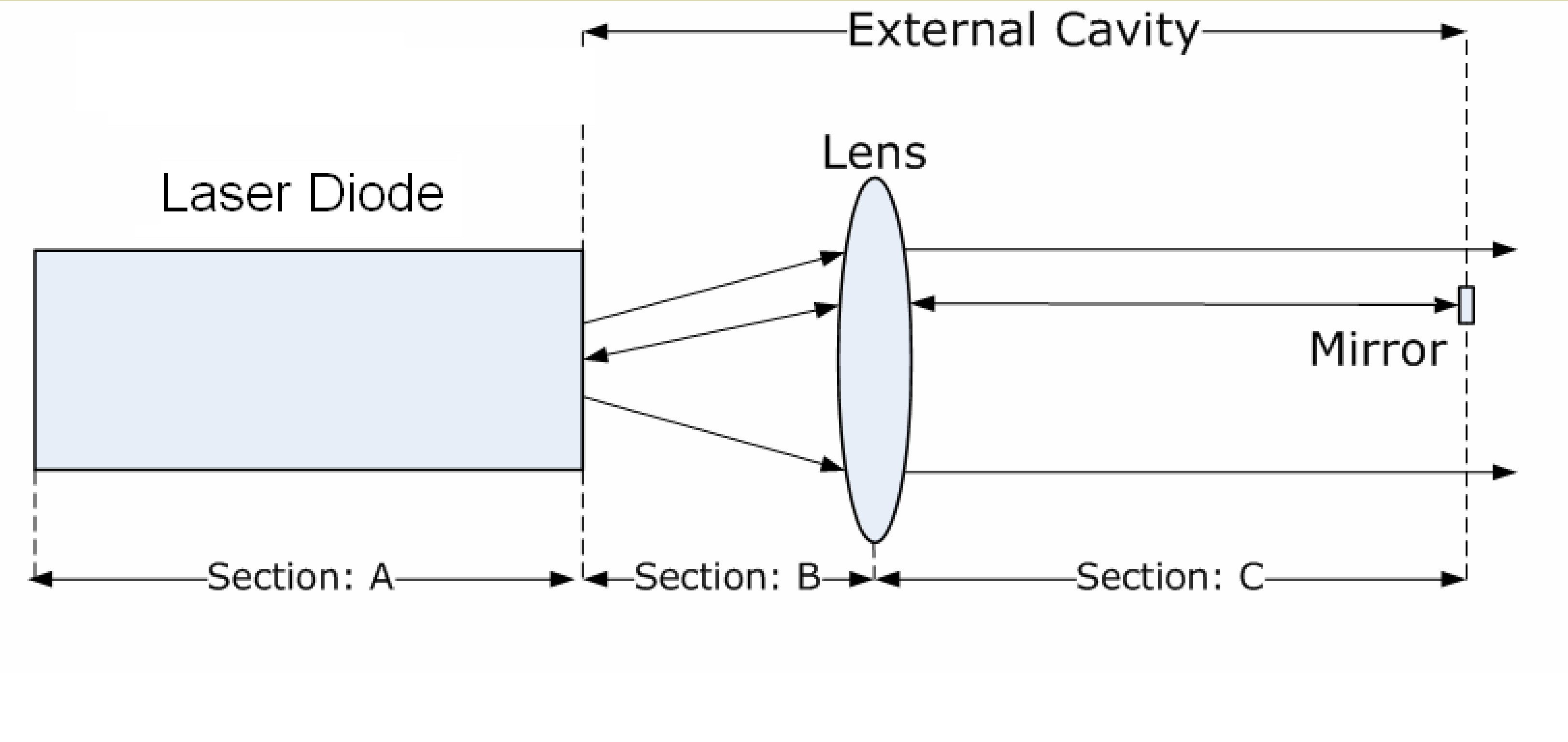


The width of the mirror stripe is estimated from the width of the lobe in the mirror plane.

The reflector position is chosen by starting moving the stripe from the edge to the centre of the device until stable operation is achieved.

The injection current density is kept constant (3kA/cm^2).

Physical Layout for Simulation



Briefly look back to the simulation structure.

Results

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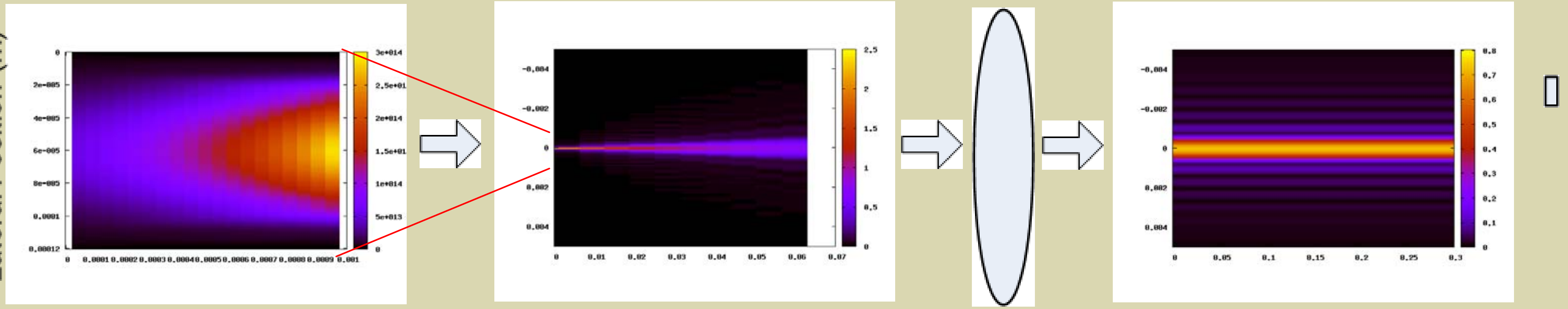
1st Roundtrip Forward Propagation

Section A | Section B | Lens | Section C | Mirror

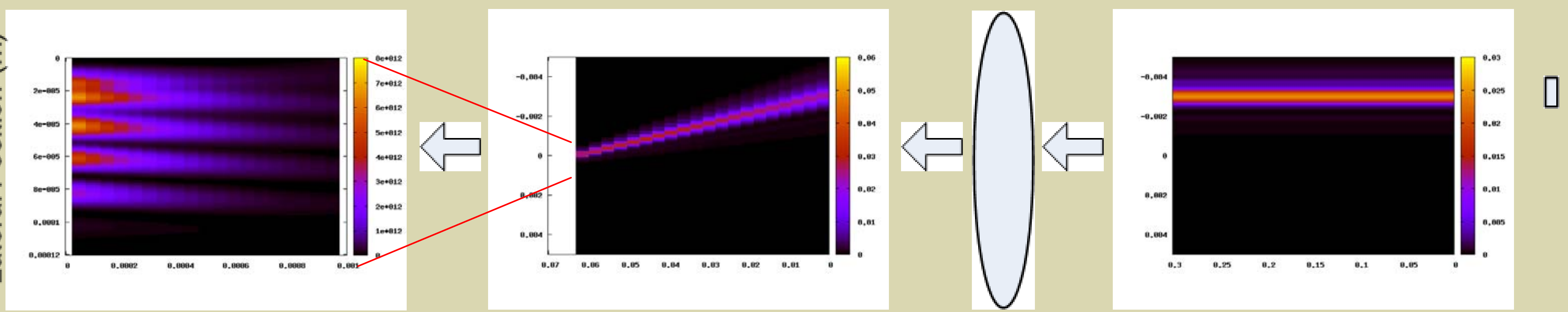
Lateral Position (m)



Propagation Position (m)

1st Roundtrip Backward Propagation

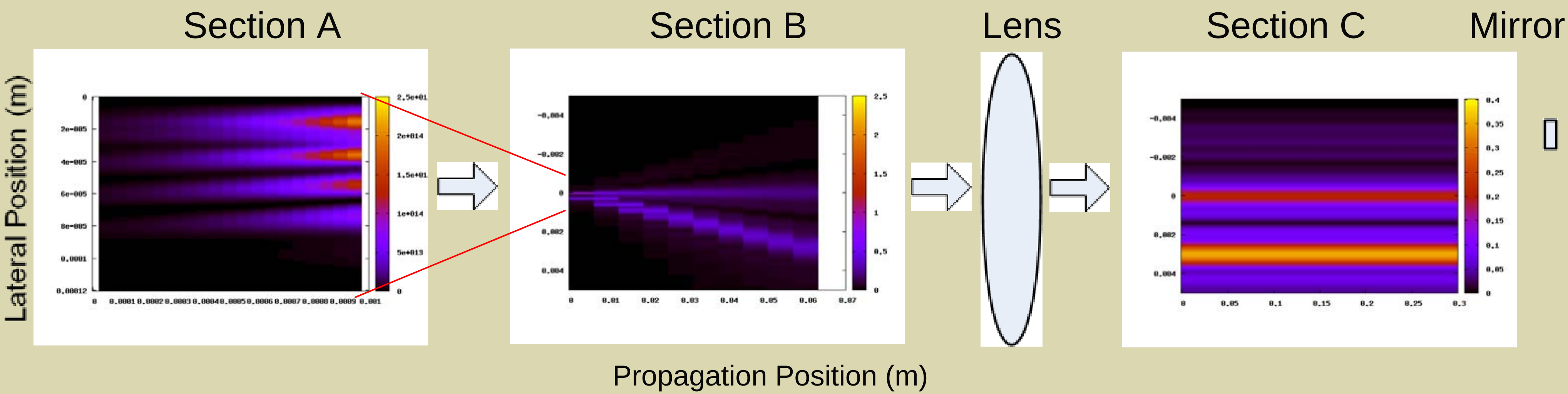
Lateral Position (m)



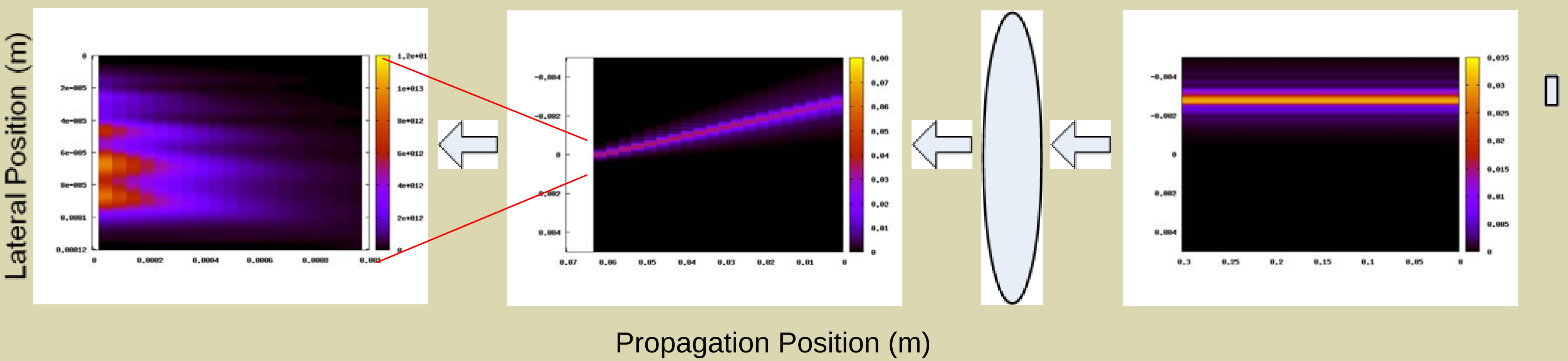
Propagation Position (m)

Results

2nd Roundtrip Forward Propagation



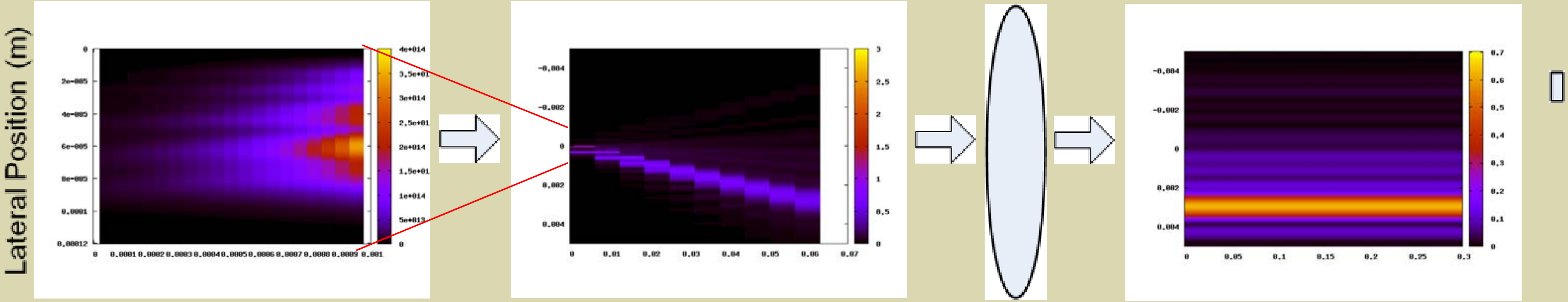
2nd Roundtrip Backward Propagation



Results

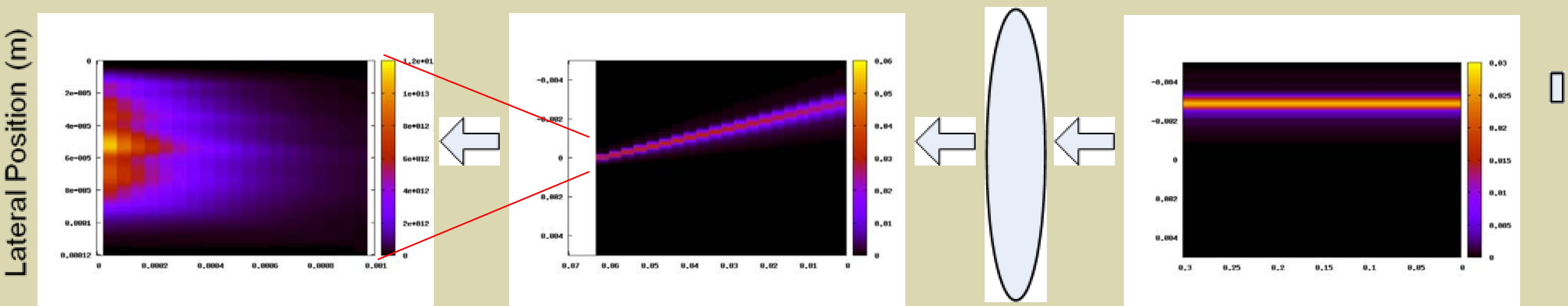
3rd Roundtrip Forward Propagation

Section A Section B Lens Section C Mirror



Propagation Position (m)

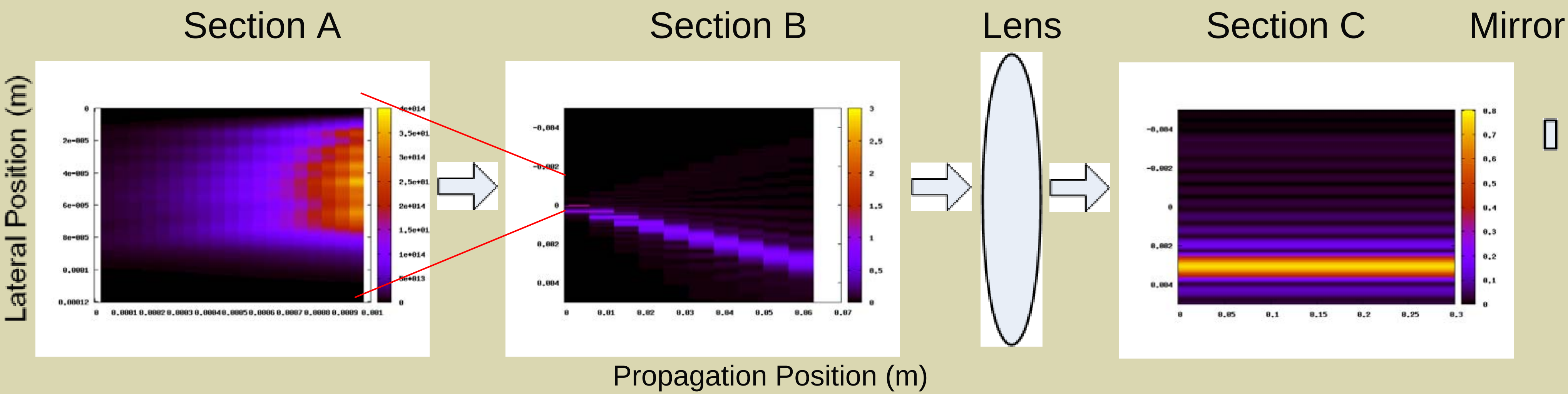
3rd Roundtrip Backward Propagation



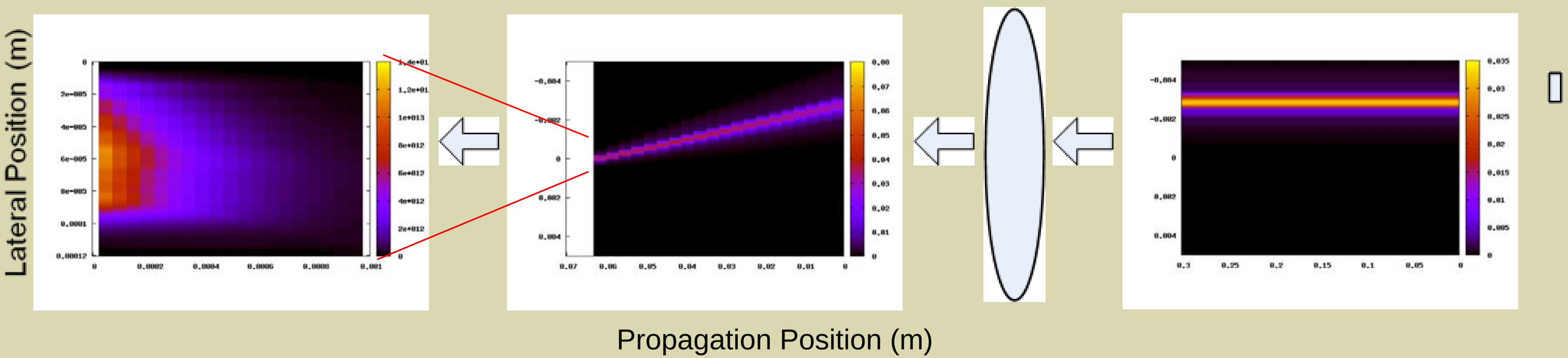
Propagation Position (m)

Results

Converged Roundtrip Forward Propagation

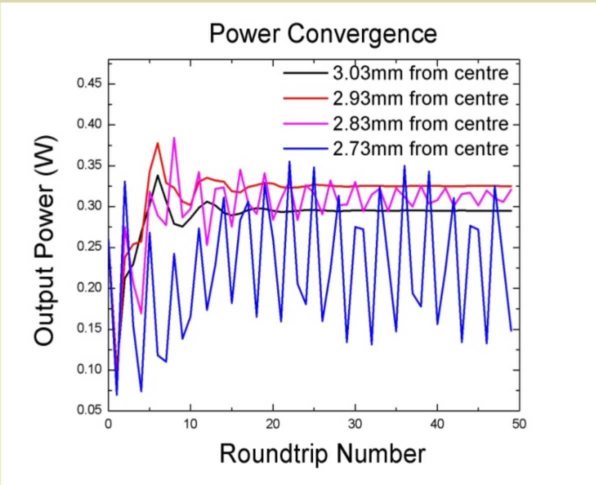


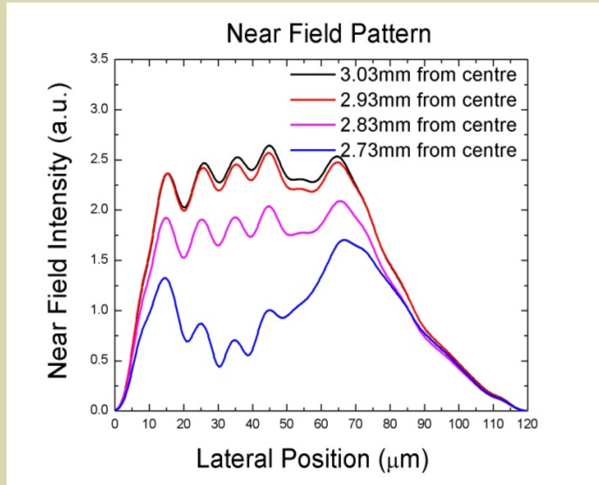
Converged Roundtrip Backward Propagation

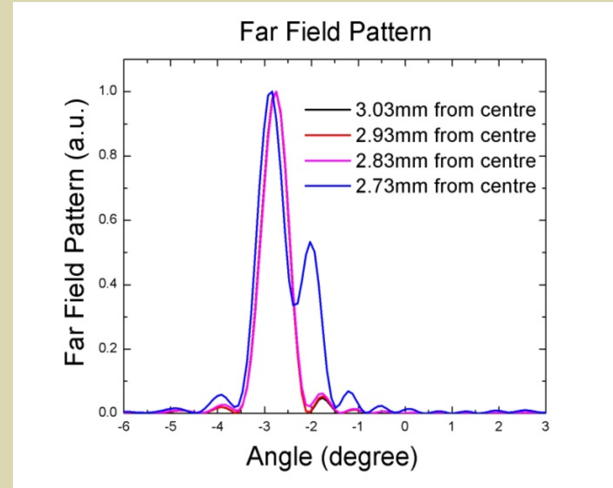


Results

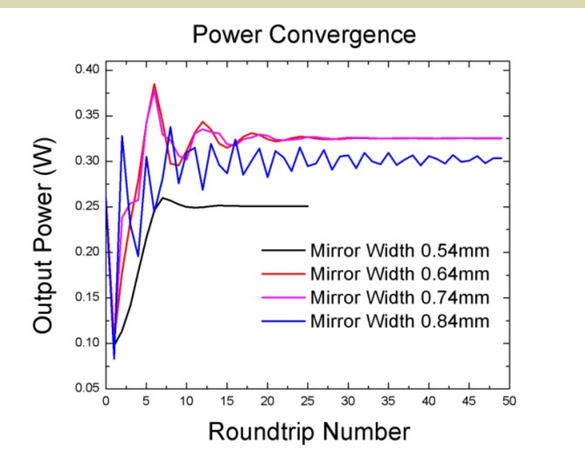
Mirror Position Sensitivity (Optimum: Position 2.93mm, Width 0.74mm)

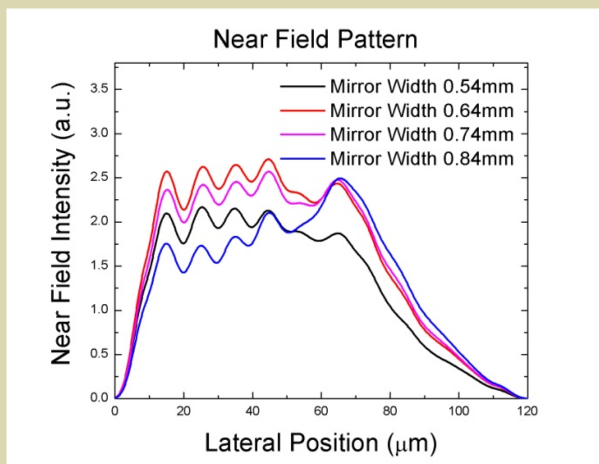


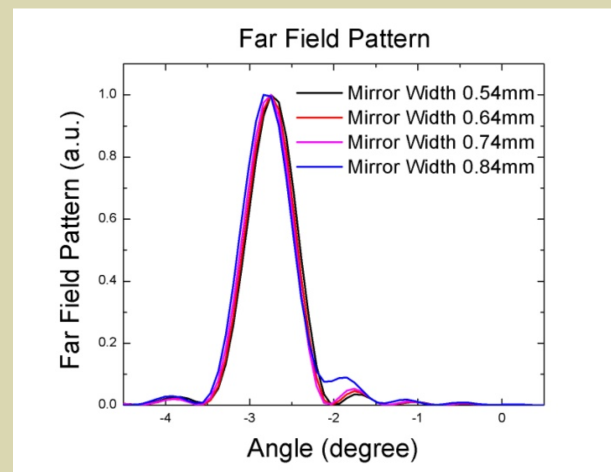




Mirror Width Sensitivity







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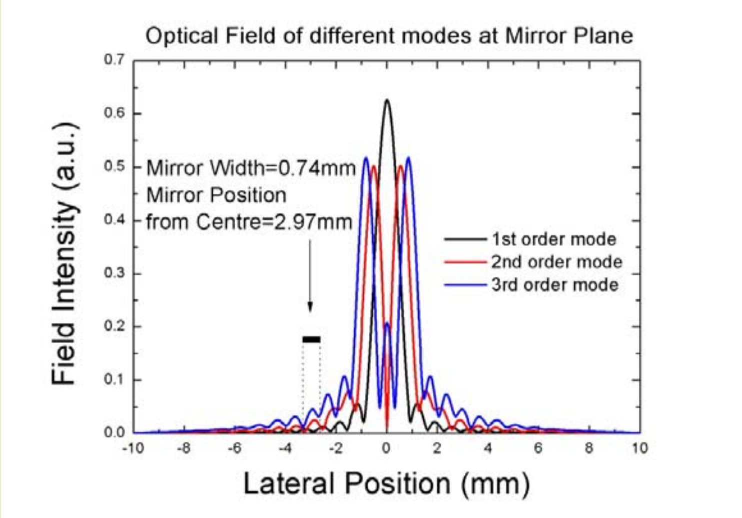
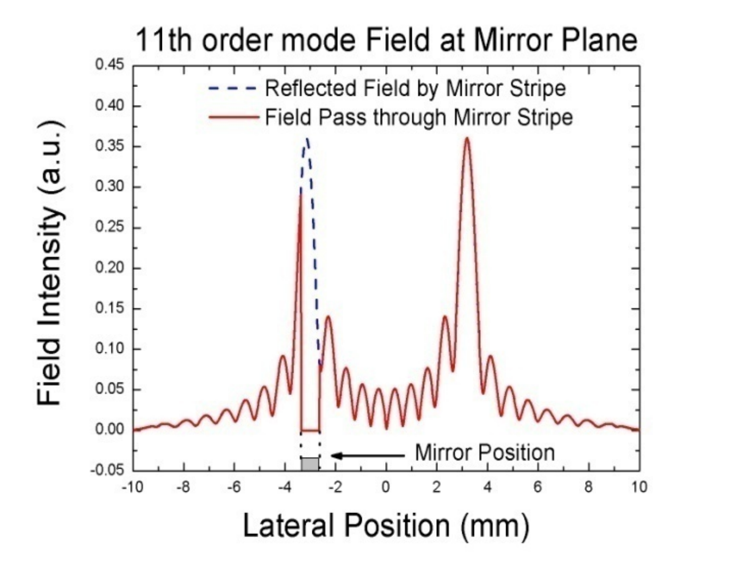
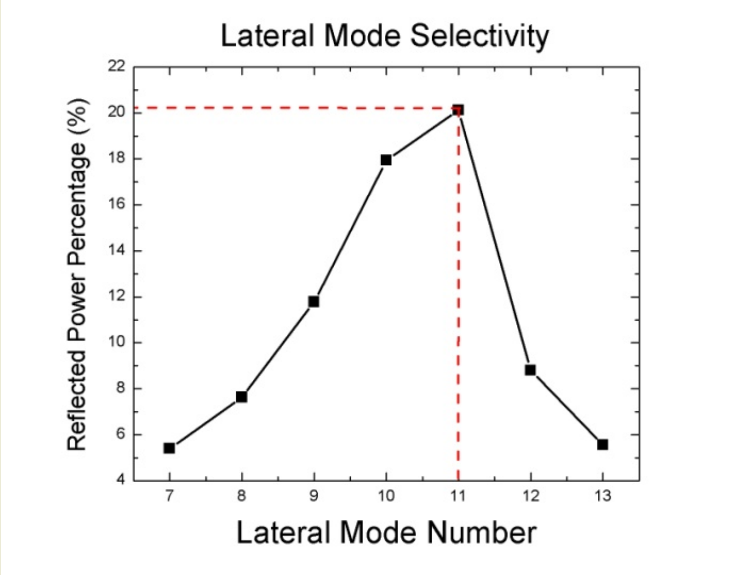
Different initial excitation

Lobe Position depend on lateral mode number

Here, the 11^{th} order mode is selected.



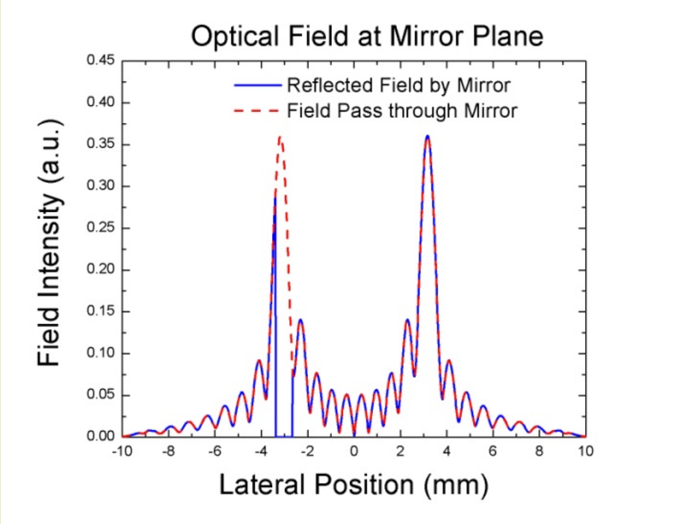


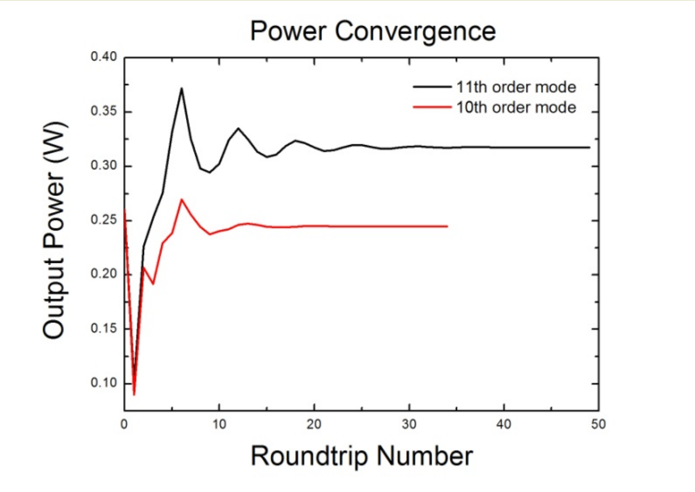


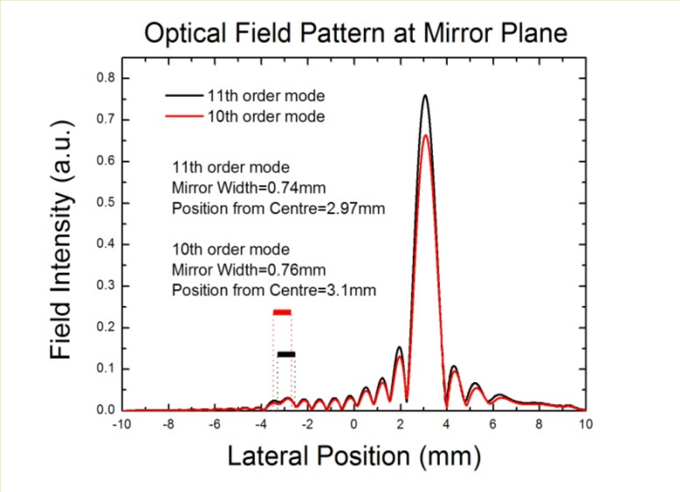
10th order mode Selection

Can the other modes (e.g. 10th order mode) be selected?

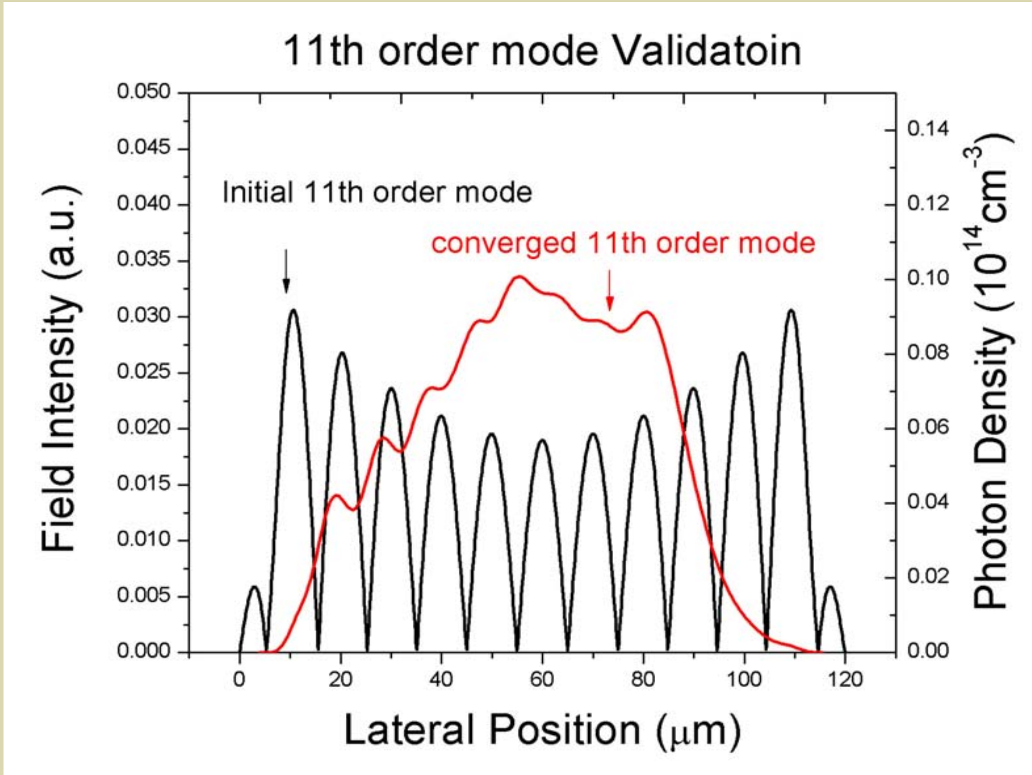
The initial guess of 10th order mode is chosen to determine the mirror position / width. A converged solution is also obtained.







Is the situation that simple?



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Conclusion

- In this work, the asymmetric feedback from an external cavity is used to select an appropriate lateral mode.
- The mirror width and position is adjusted carefully to a optimum operating condition.
- The selected lateral mode dominates the lasing process inside the laser cavity and the other modes are then suppressed efficiently. The beam quality is improved significantly.

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Thank you!

Questions?