

# **Spatial Chirp Effect in Virtually Imaged Phased Array (VIPA) Wavelength Demultiplexor**

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Conference on Lasers and Electro Optics 2003  
Baltimore, MD. June 4, 2003

Support From National Science Foundation, Army Research Office

# Outline

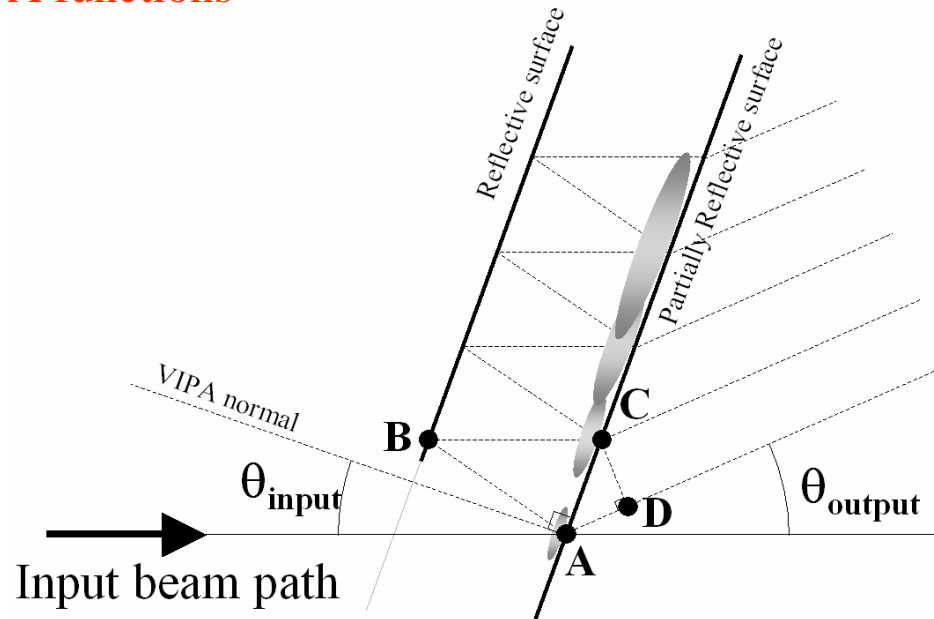
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- **VIPA vs. Diffraction Gratings**
  - Large angular dispersion
  - Low polarization sensitivity  
(M. Shirasaki, Optics Letter 1996)
  - Chromatic dispersion compensation  
(M. Shirasaki, IEEE Photonics Tech. Letter 1997 and OFC 2001)
- **VIPA Demultiplexor Spectrum**
  - Review of previous publication
  - Symmetric and asymmetric VIPA demultiplexor spectrum
  - Spatial chirp effect

# VIPA vs. Diffraction Gratings

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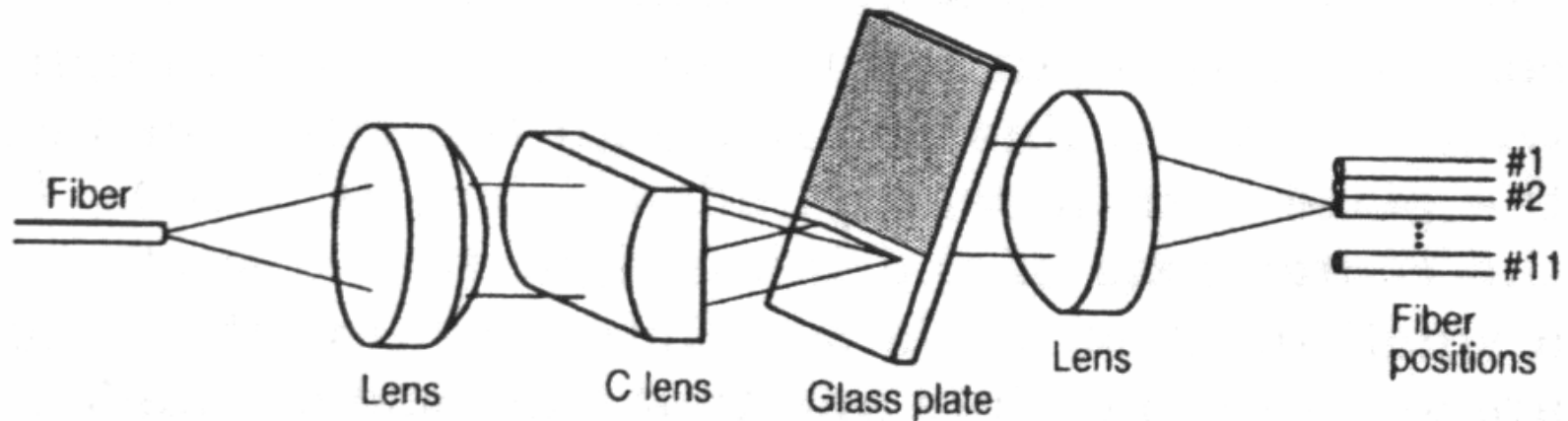
## ➤ How VIPA functions



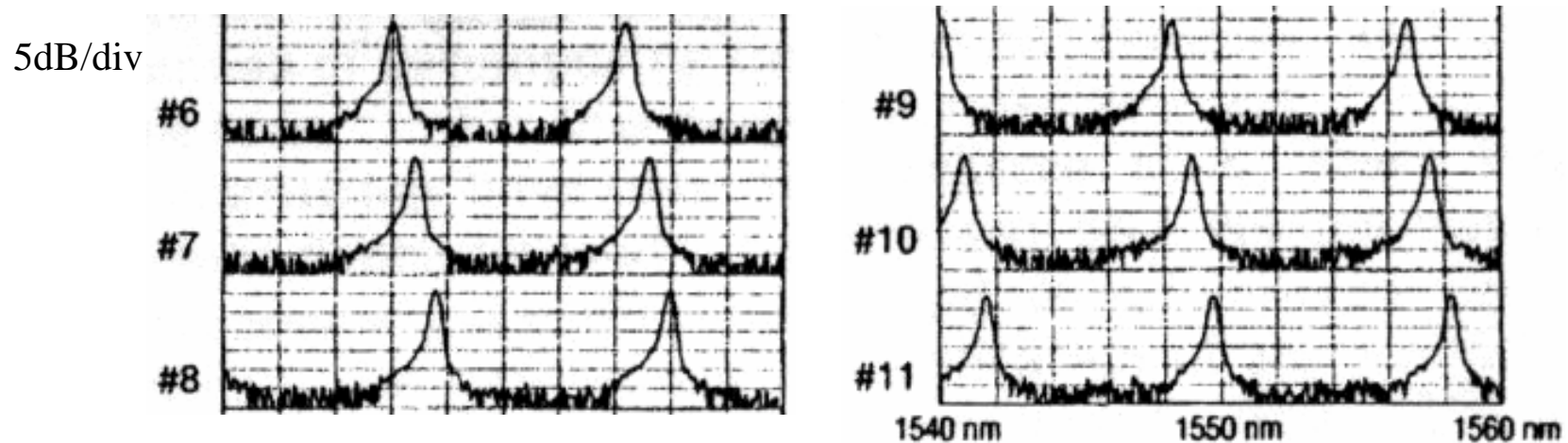
## ➤ Advantages (M. Shirasaki, Optics Letters, Vol. 21, No. 5, March 1, 1996)

- ✓ VIPA has a 10- 20 times larger angular dispersion than common gratings, which is proportional to  $ctg(\theta_{input})$
- ✓ VIPA has a low polarization sensitivity, simple structure, low cost, and compactness

# VIPA Wavelength Demultiplexor

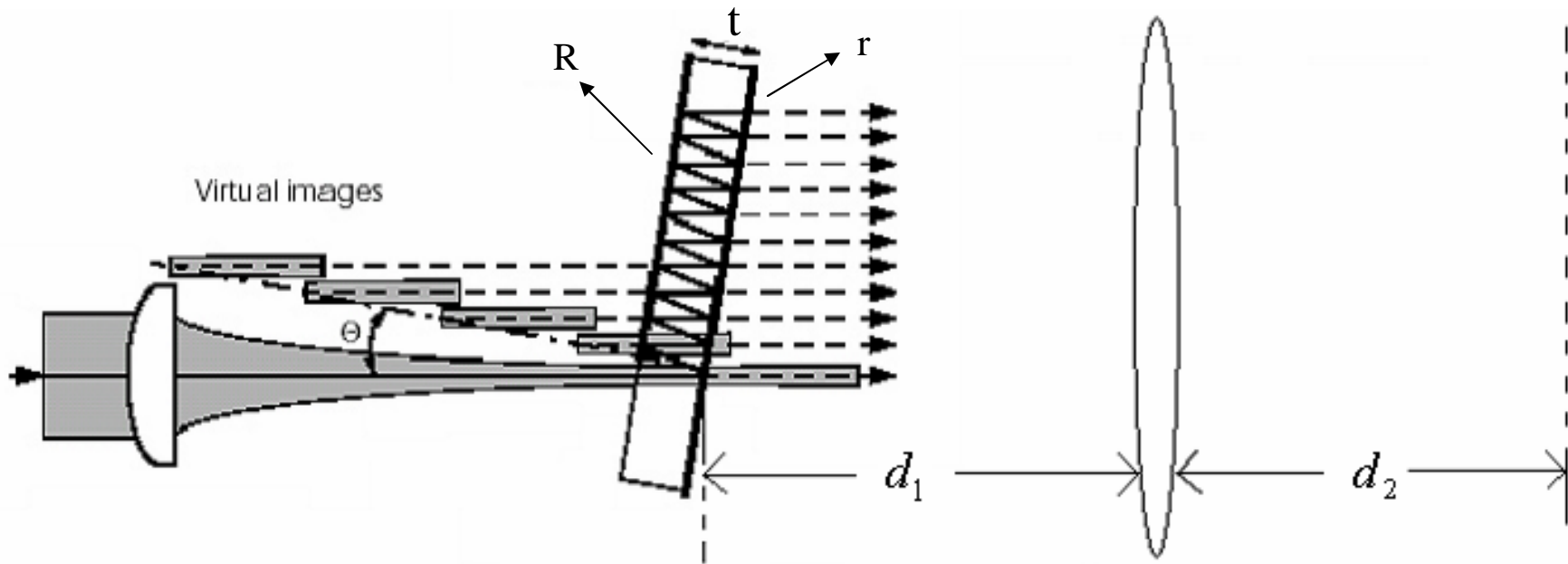


(M. Shirasaki, Optics Letters, Vol. 21, No. 5, March 1, 1996)



Same phenomena in A. Vega, A. M. Weiner, C. Lin, Applied Optics, In Press

# VIPA Theory Model



- Each source has a non-chirp Gaussian profile  $E_0 \exp\left(-\frac{x^2}{w_0^2}\right)$
- The  $n$ th source has profile ( $n= 0, 1, 2, \dots$ )

$$E_0 (Rr)^n \exp\left[-\frac{(x - n2t \sin \theta)^2}{w_0^2}\right] \quad d_{1_n} = F + n2t \cos \theta$$

# Theory of VIPA Demultiplexor Spectrum

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- General Lens Transformation

$$E_{out}(x_F, \lambda) \propto \exp\left[-i \frac{k}{2d_2} \left(\frac{1}{qd_2} + 1\right) x_F^2\right] \int E_{in}(x) \exp\left[-i \frac{k}{2d_1} \left(\frac{1}{qd_1} + 1\right) x^2\right] \exp\left(-i \frac{kx_F x}{qd_1 d_2}\right) dx$$

$$q = \frac{1}{F} - \frac{1}{d_1} - \frac{1}{d_2}$$

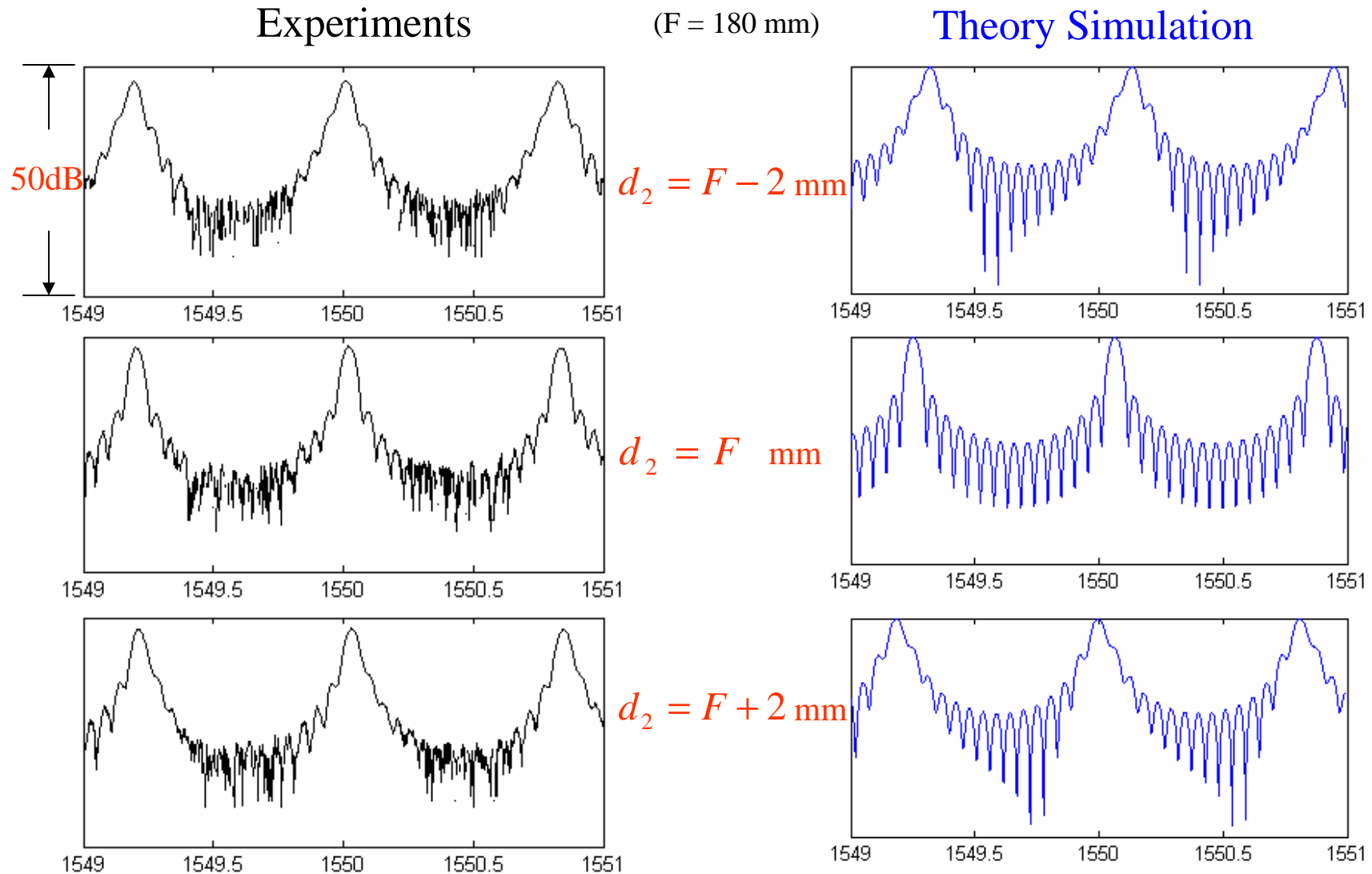
- The field at the origin of the receiving plane

$$E_{out}(\lambda) \propto \sum_n (Rr)^n \exp[-ikn2t \cos(\theta_i)] \exp[-ib4n^2 t^2 \sin^2(\theta_i)]$$

$$b = \frac{k}{2d_1} \left(1 + \frac{1}{qd_1}\right) = \frac{k}{2} \frac{d_2 - F}{d_1 d_2 - d_1 F - d_2 F}$$

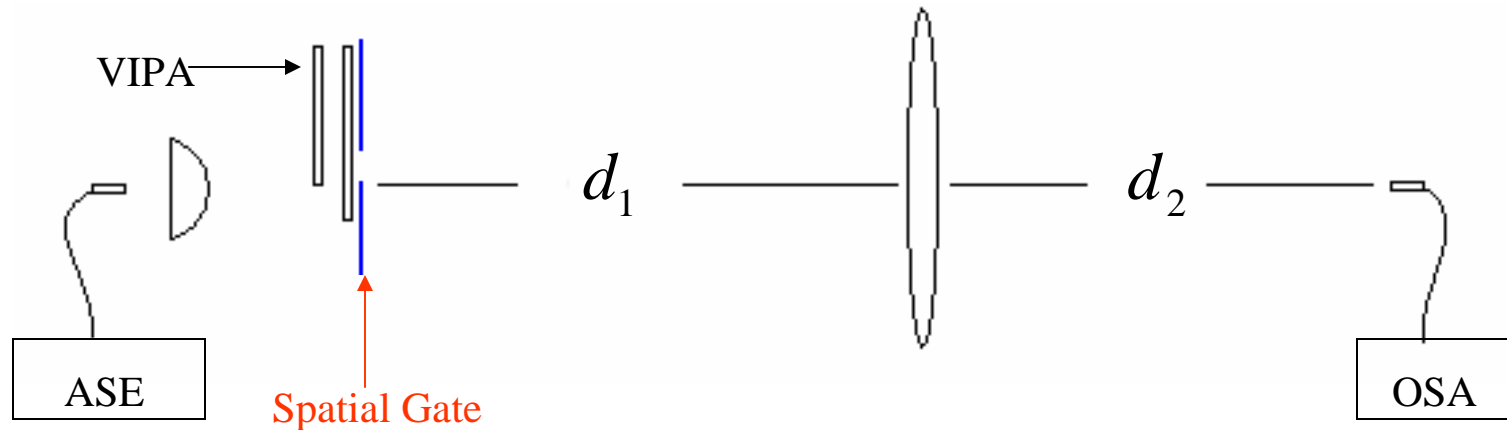
- The demultiplexor spectrum is very sensitive on  $d_2$  within the focal depth region.
- The spectrum is only weakly dependent on  $d_1$ .

# VIPA Demultiplexor Power Spectrum



# Our Setup with Spatial Gate

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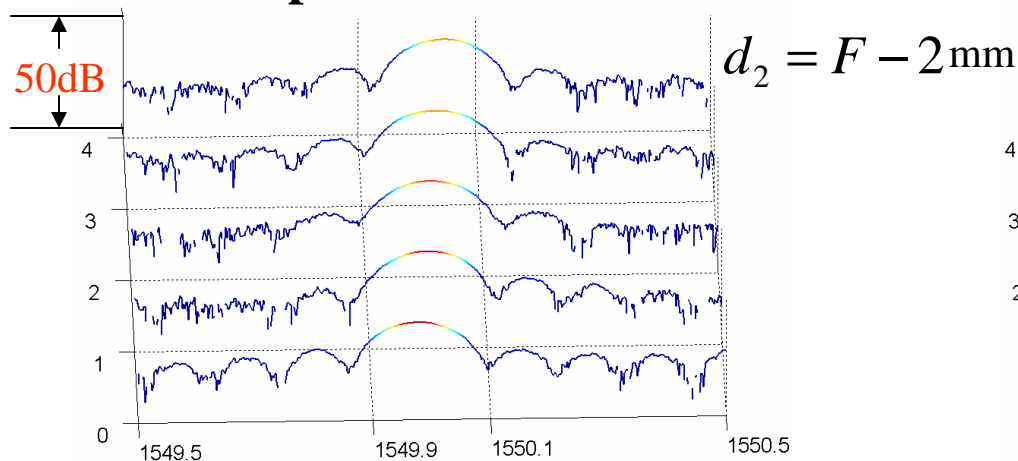


ASE: Amplified Spontaneous Emission; OSA: Optical Spectrum Analyzer  
OSA resolution is 0.01 nm

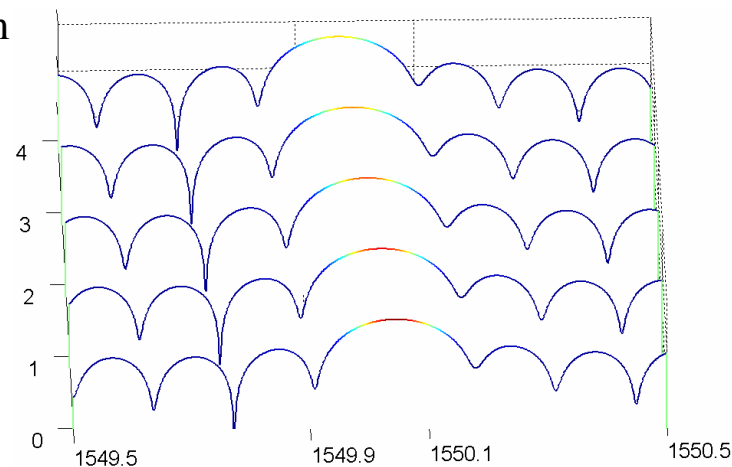
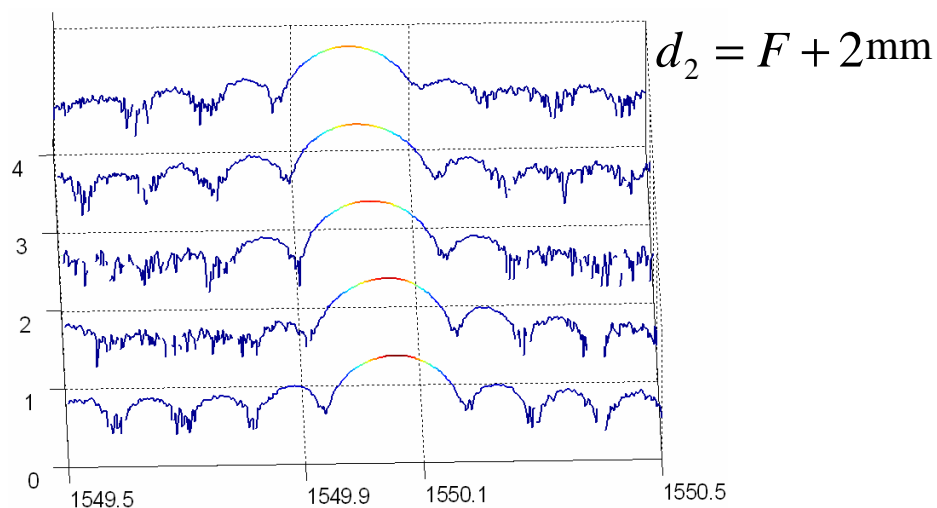
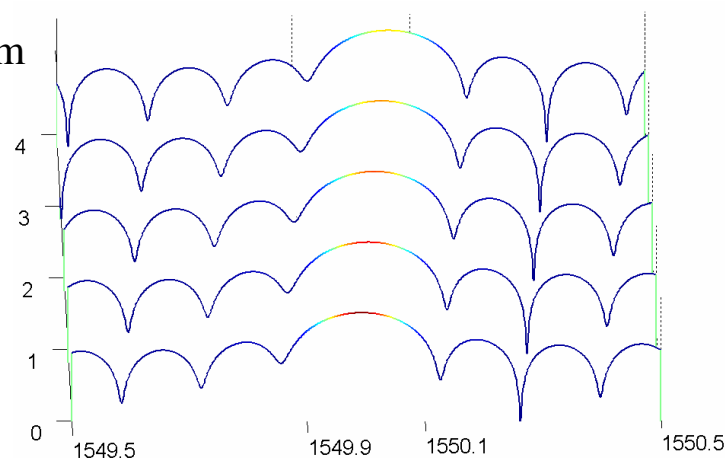
- We introduce a spatial gate to look at the contribution from different sets of multiple beam spots
- The setup allows us to have a closer look how spectral asymmetry occurs

# Gated Power Spectrum

## Experiments

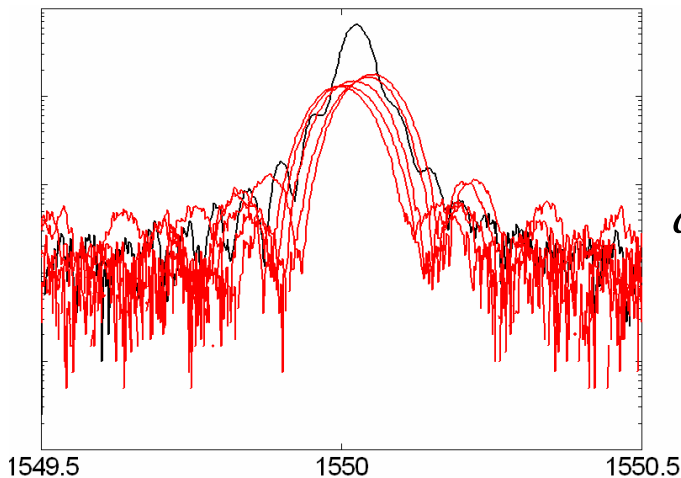
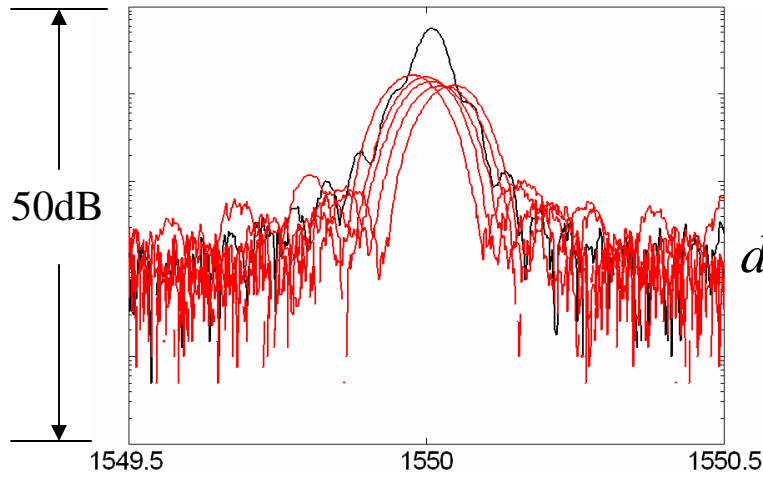


## Theory Simulation

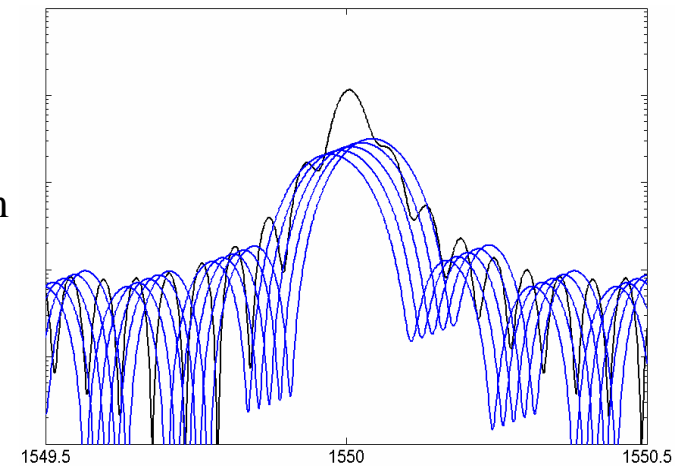
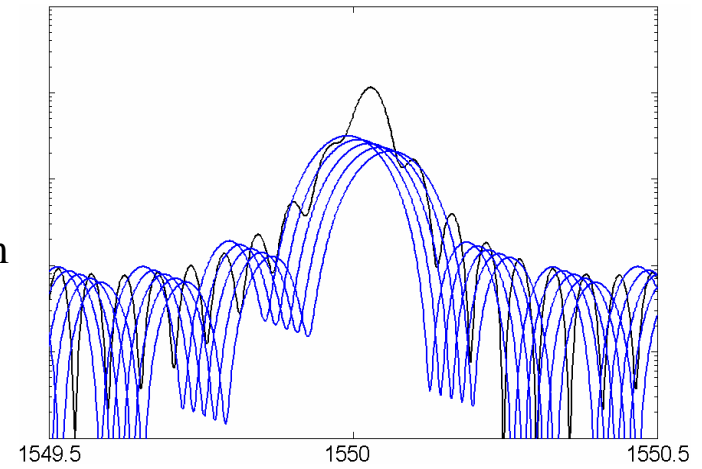


# Asymmetry Effects

## Experiments

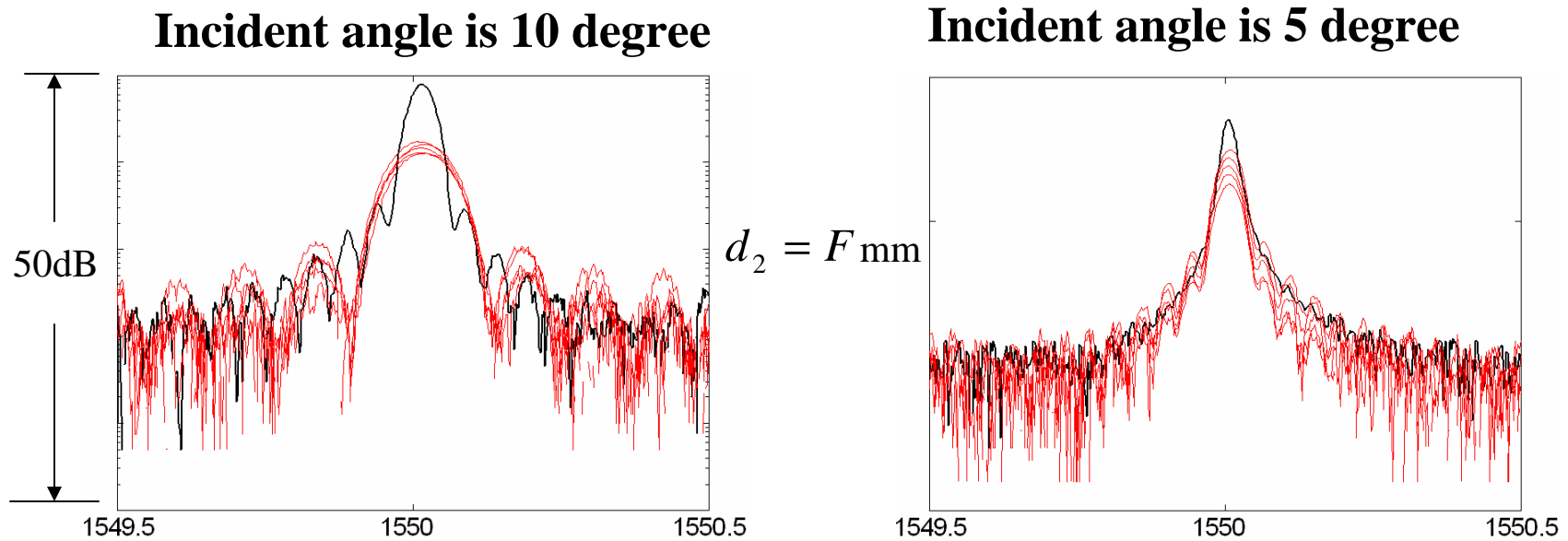


## Theory Simulation



( $F = 180 \text{ mm}$ )

# Symmetry and Discussions



$F = 180$  mm

- We can obtain spatial chirp-free spectrum when  $d_2 = F$
- Line-shape asymmetry when  $d_2 \neq F$  is associated with spatial chirp effect

( $d_2$  is the longitudinal distance between the focusing lens and the receiver)

# Summary

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- We explain the **symmetric behavior** of VIPA demultiplexor line-shape  
Spectral symmetry or asymmetry strongly depends on receiver's longitudinal position
- We identify a **spatial chirp effect** strongly related to line-shape asymmetry
- Our results are fully explained by our theory