

Optical microring resonator filter design trade-offs

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- **Microring resonator:**

 - Structure and operation as filter

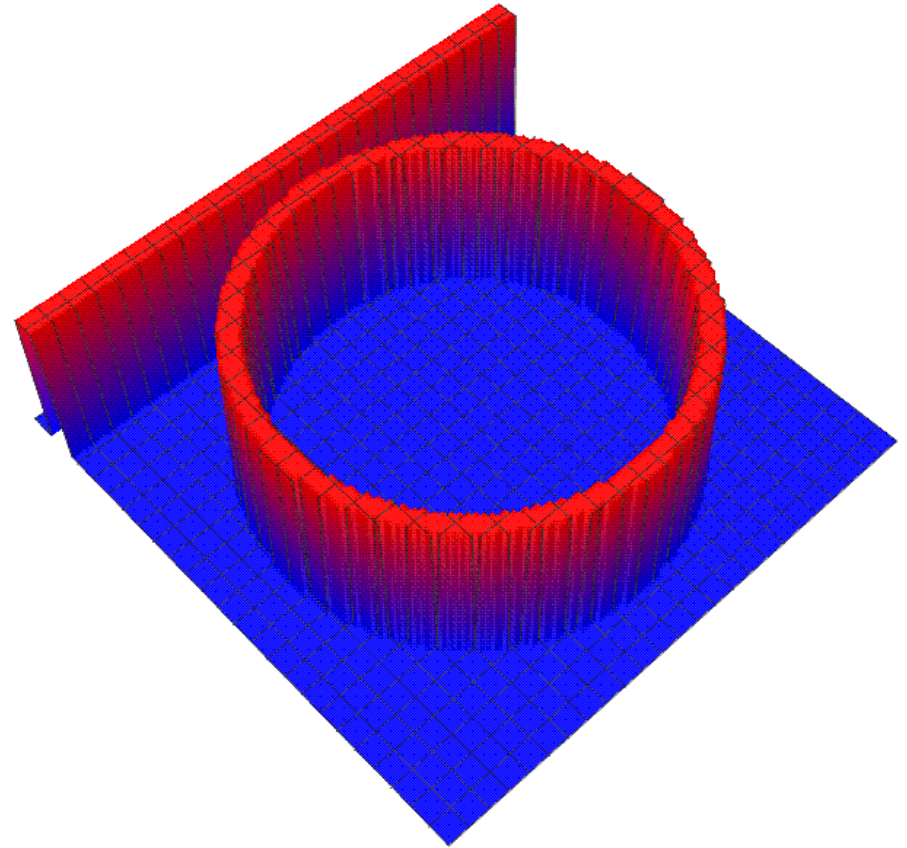
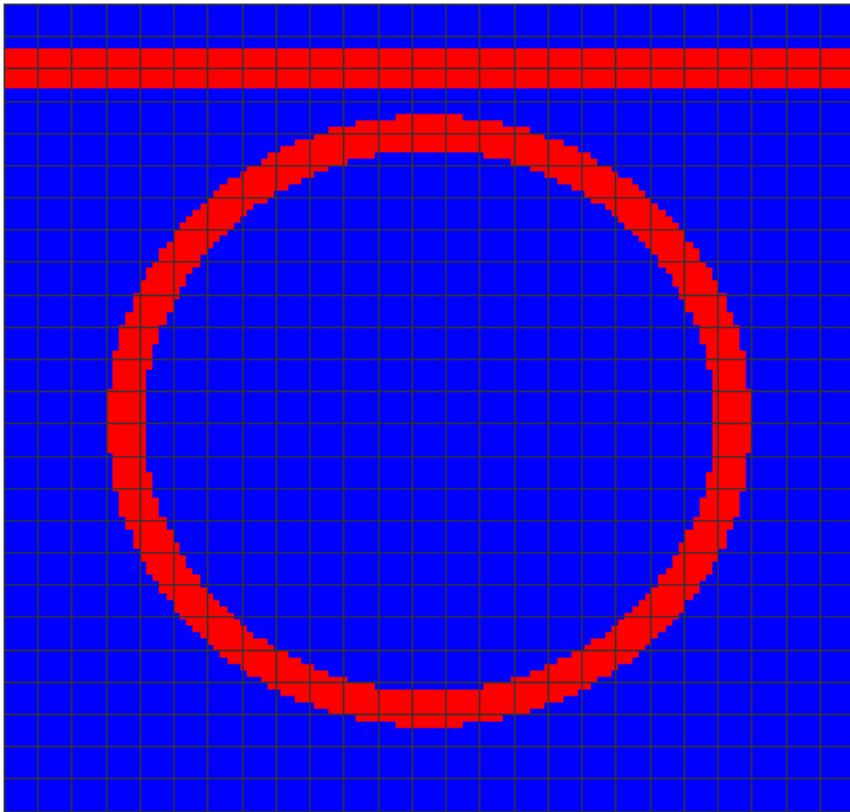
 - Trade-offs in design, size, loss, Q, energy

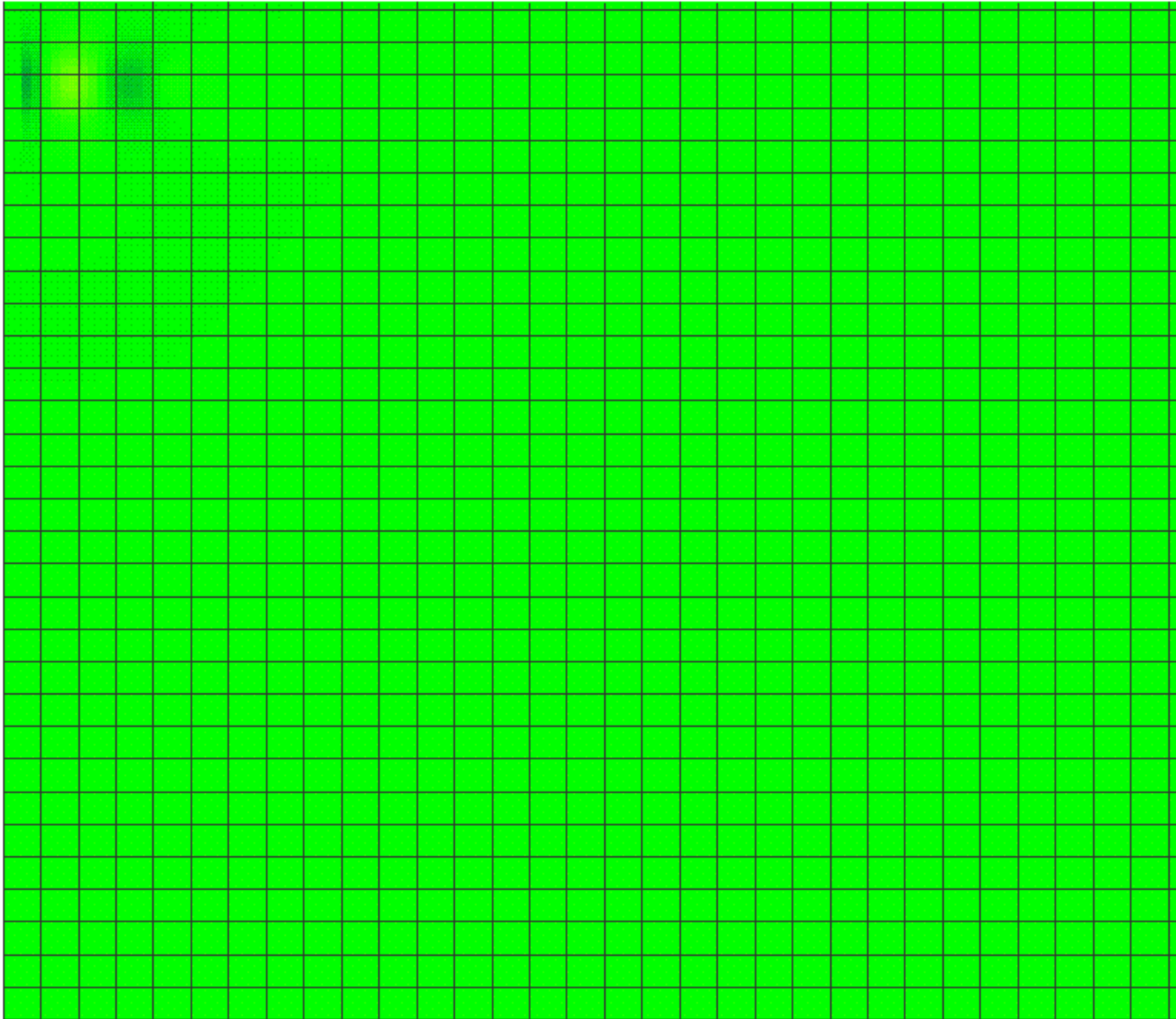
- **Improvement using Bragg reflector**

 - Simulation results show reduced loss

 - Trade-offs in Bragg structure

Layout of a Ring Resonator





Optimal design and coupling

- **For resonance:**

Average length of ring is:

$$L = m (\lambda/n)$$

where n is average refractive index of field

- **For optimum cancellation at resonance**

Transmission loss t = loss once around ring

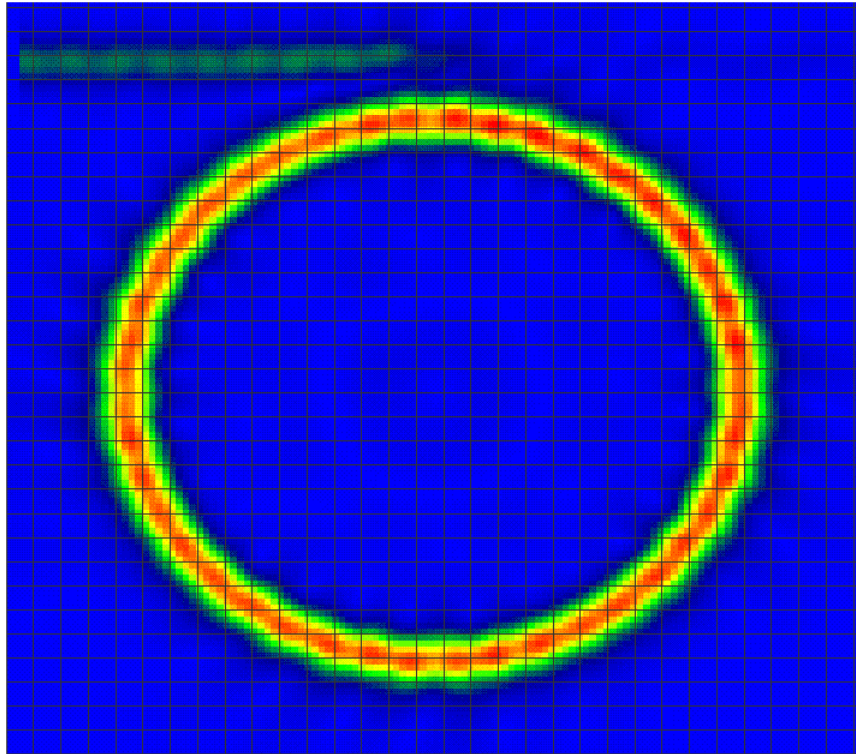
$$t = x,$$

satisfies minimum from transmission:

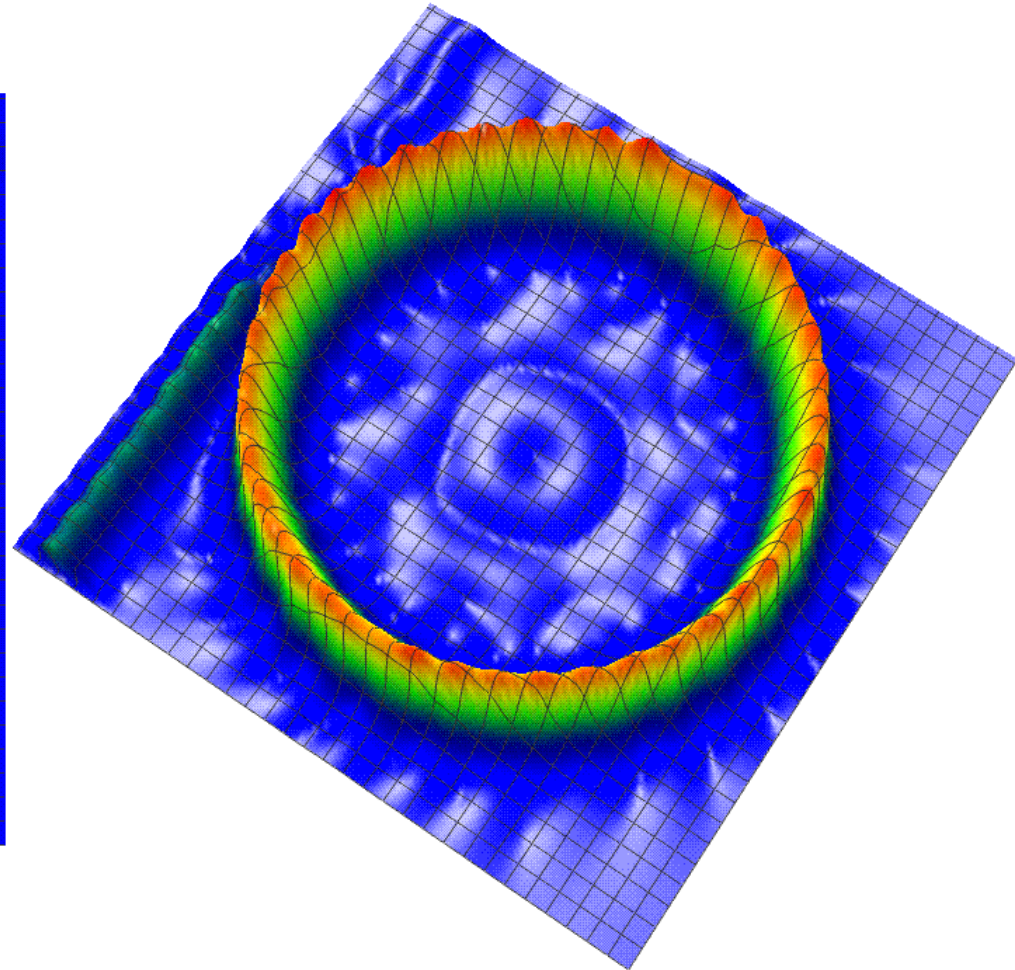
$$T = (x-t)^2 / (1-xt)^2$$

- **Coupling** $1-t^2$ depends on separation and λ/n

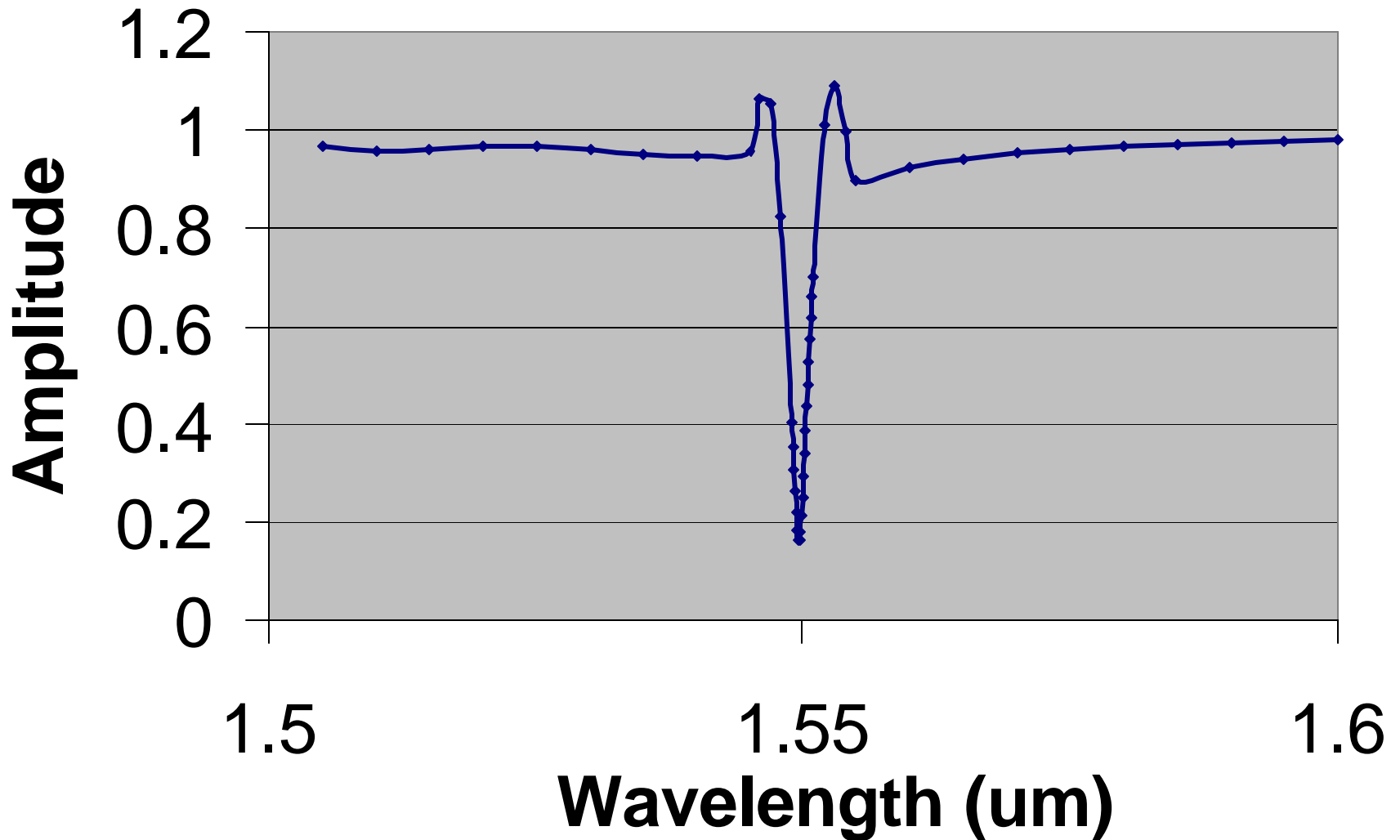
Ey Amplitude of a Resonating Ring Filter



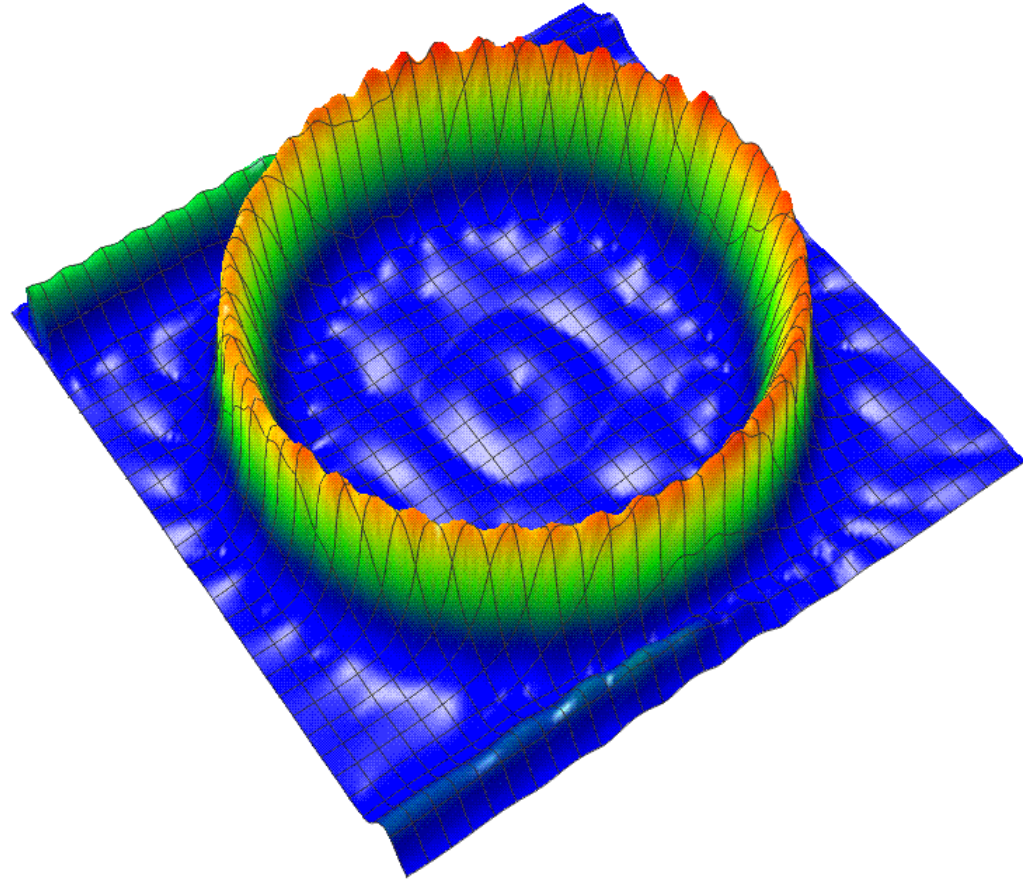
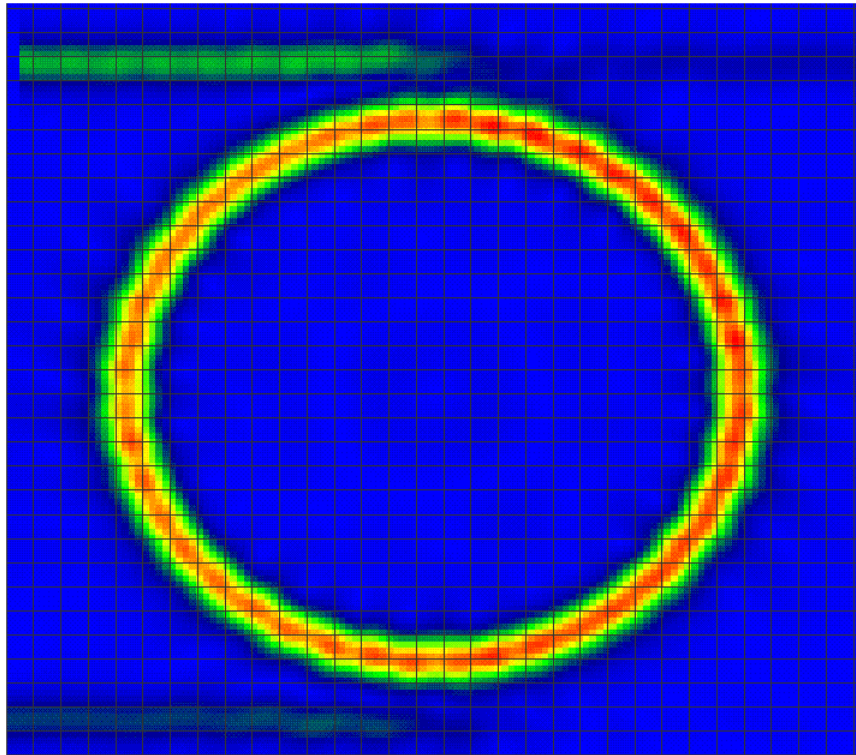
Radius = 1.8 μ m



Output Amplitude Vs. Wavelength

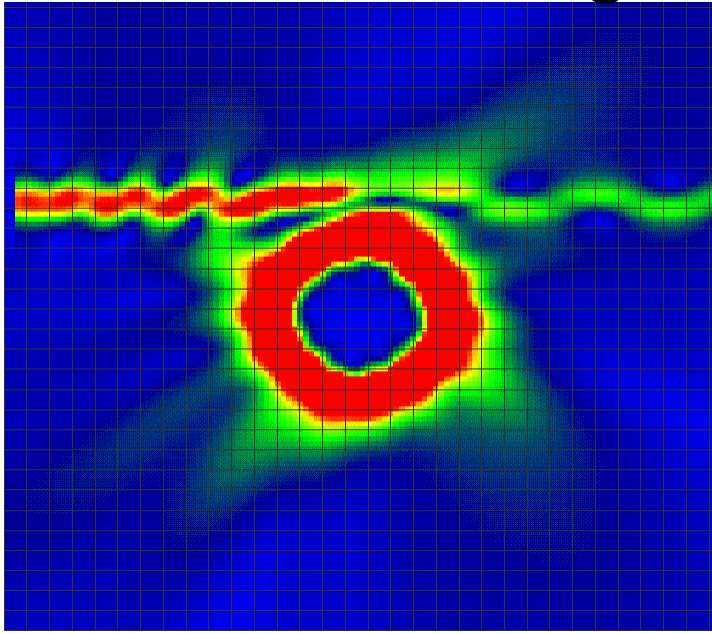


Ey Amplitude of a Resonating Ring Filter with Output Waveguide

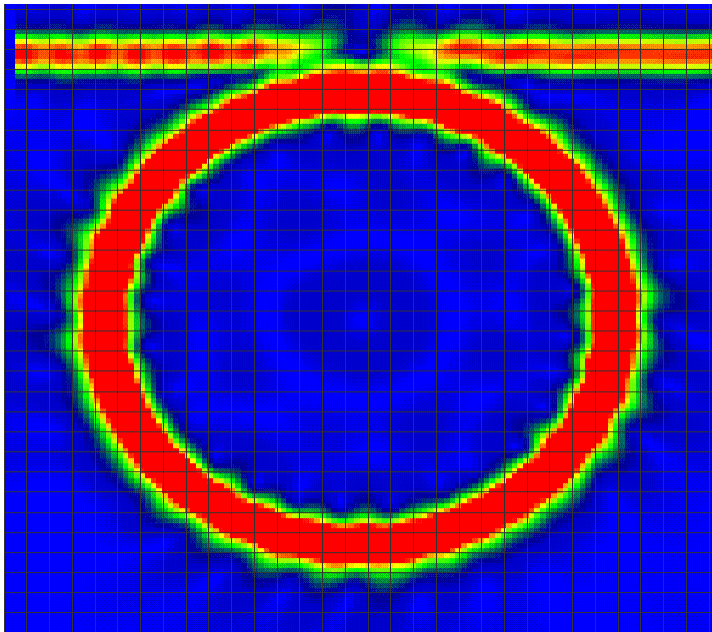
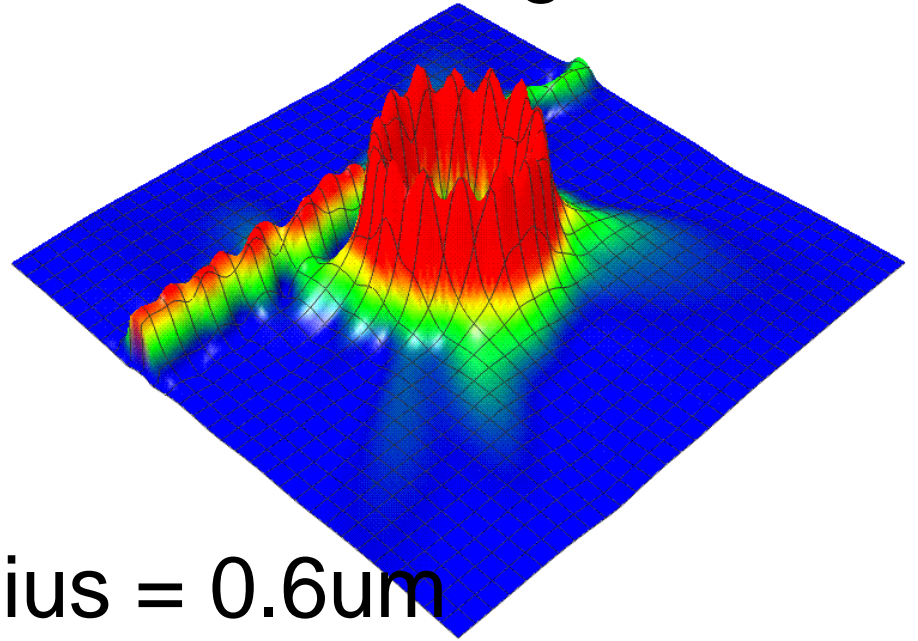


Radius = 1.8 μ m

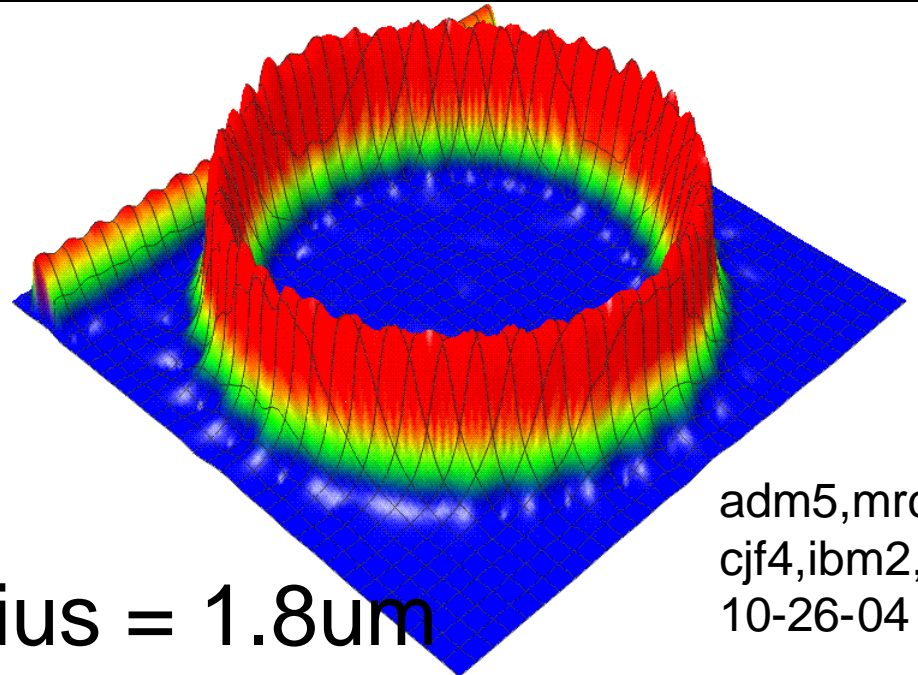
Loss of a Ring Depends on the Ring Radius



Radius = 0.6 μ m



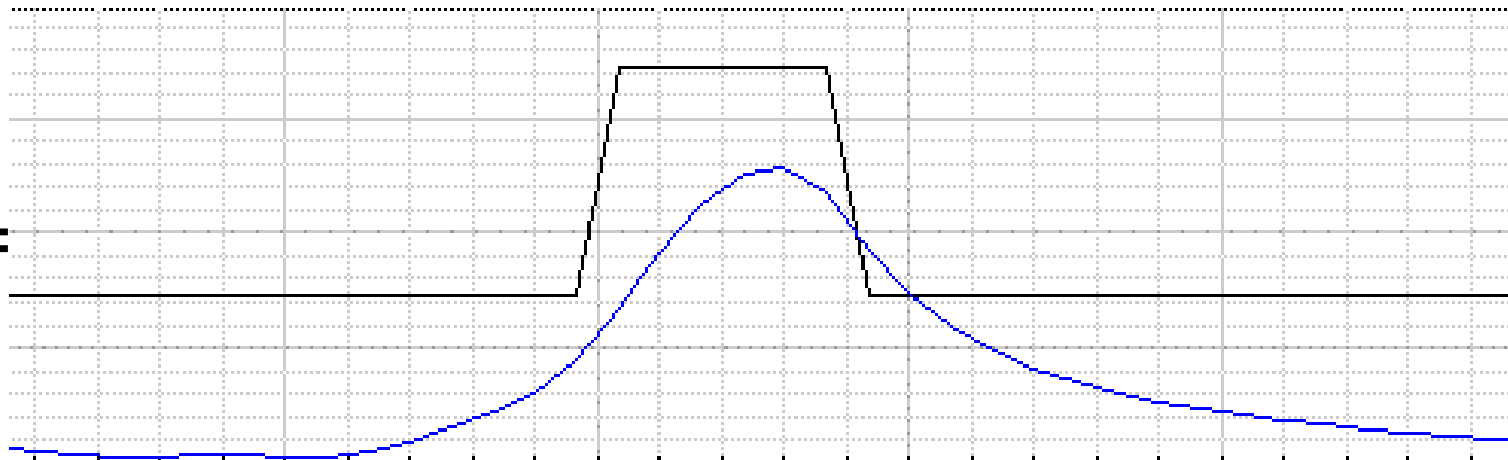
Radius = 1.8 μ m



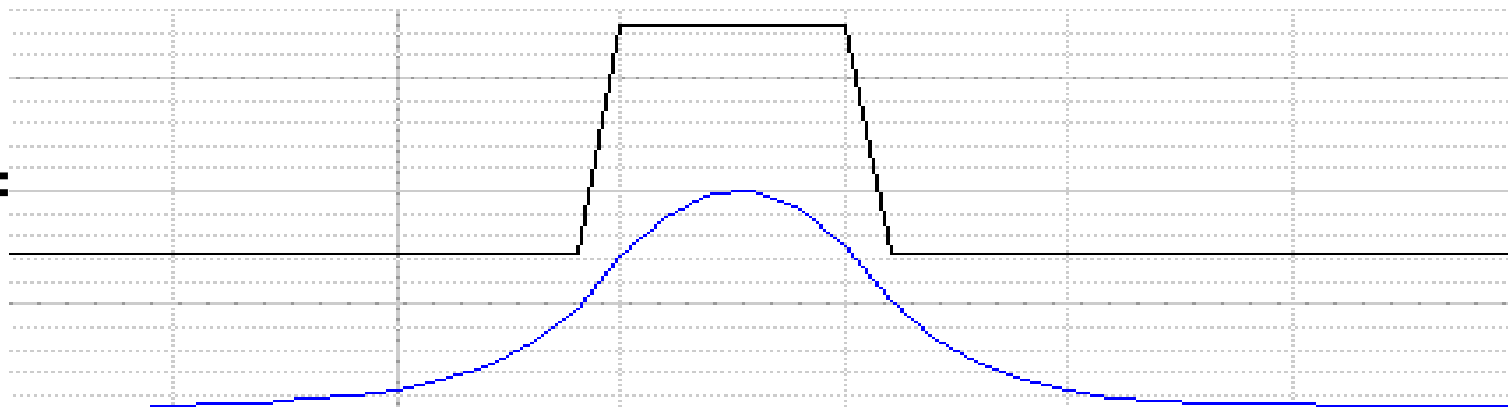
adm5,mrc7,
cjf4,ibm2,
10-26-04

Crosscut of the Rings with Different Radii

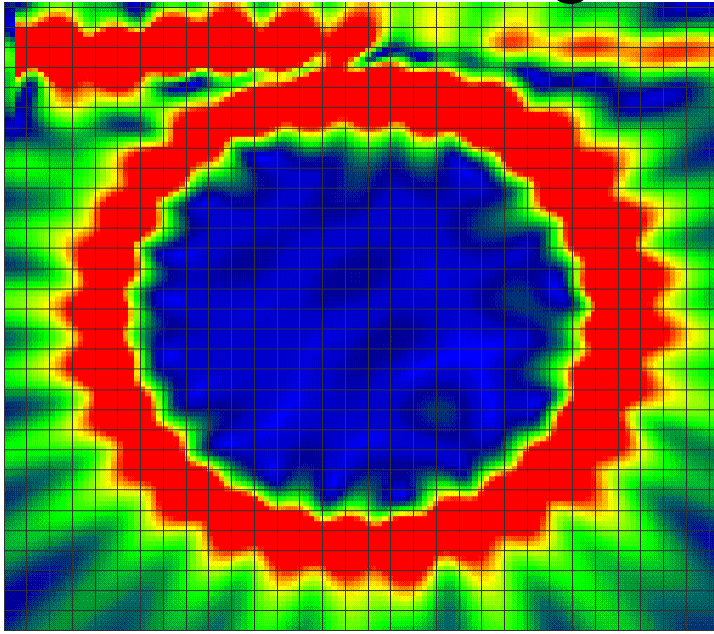
Radius =
0.6 μ m



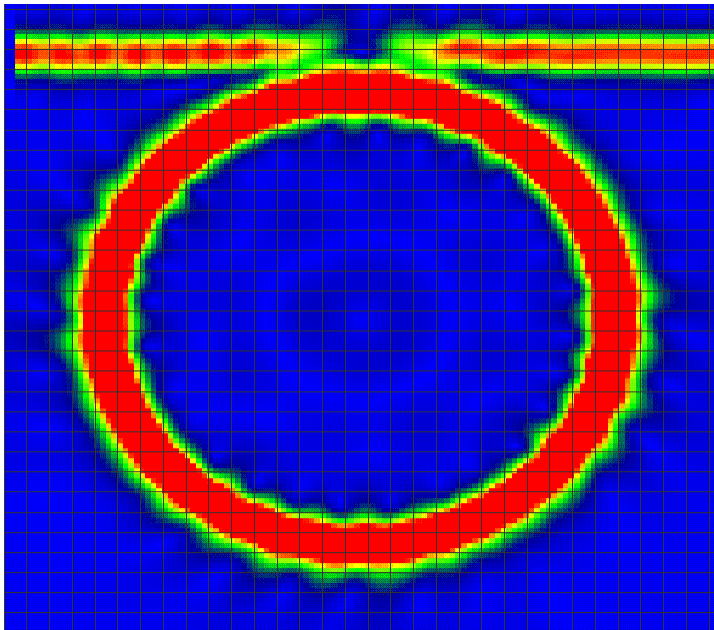
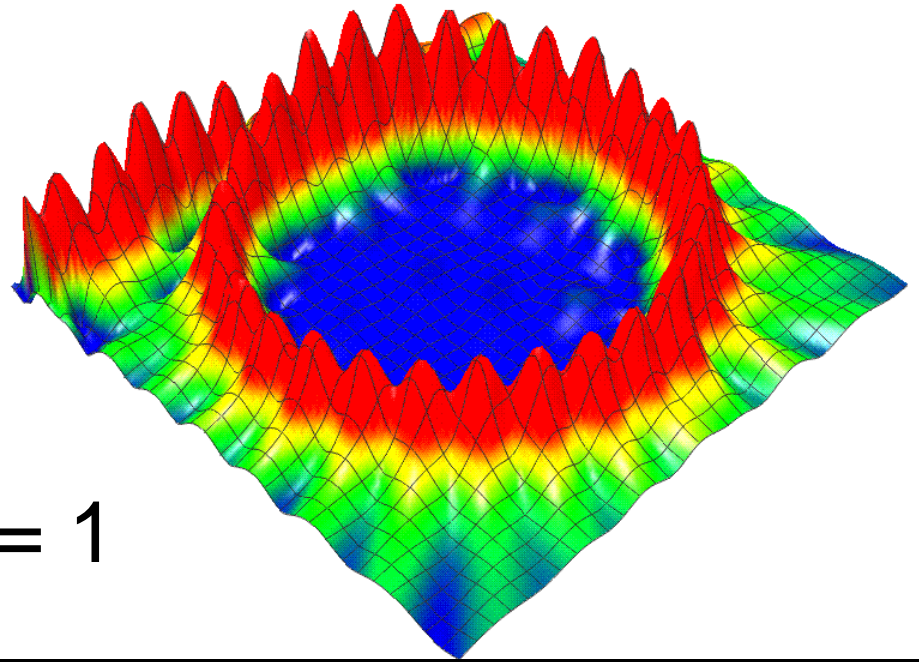
Radius =
1.8 μ m



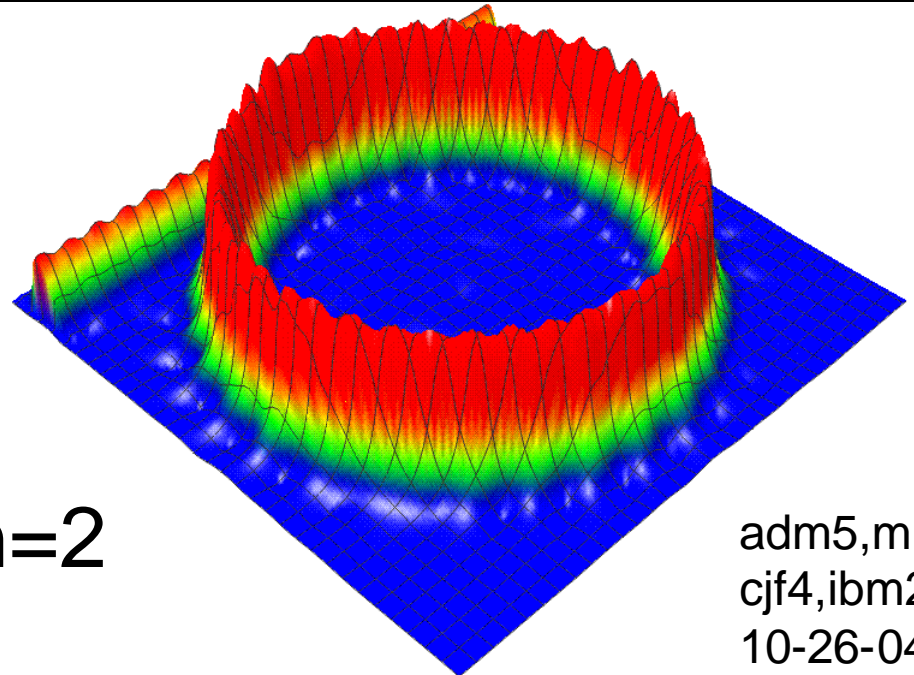
Loss of a Ring Depends on Refractive Indices



$$\Delta n = 1$$



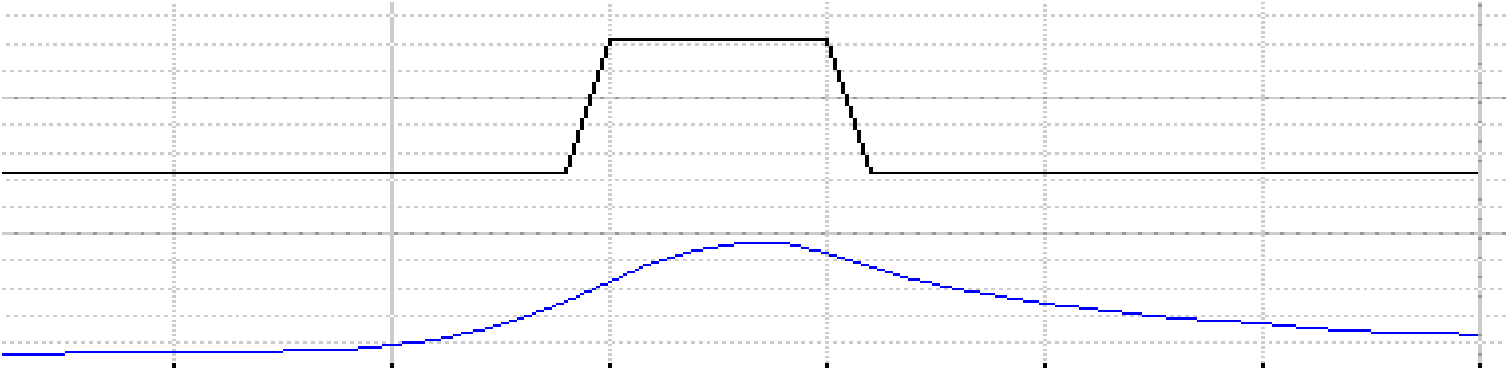
$$\Delta n = 2$$



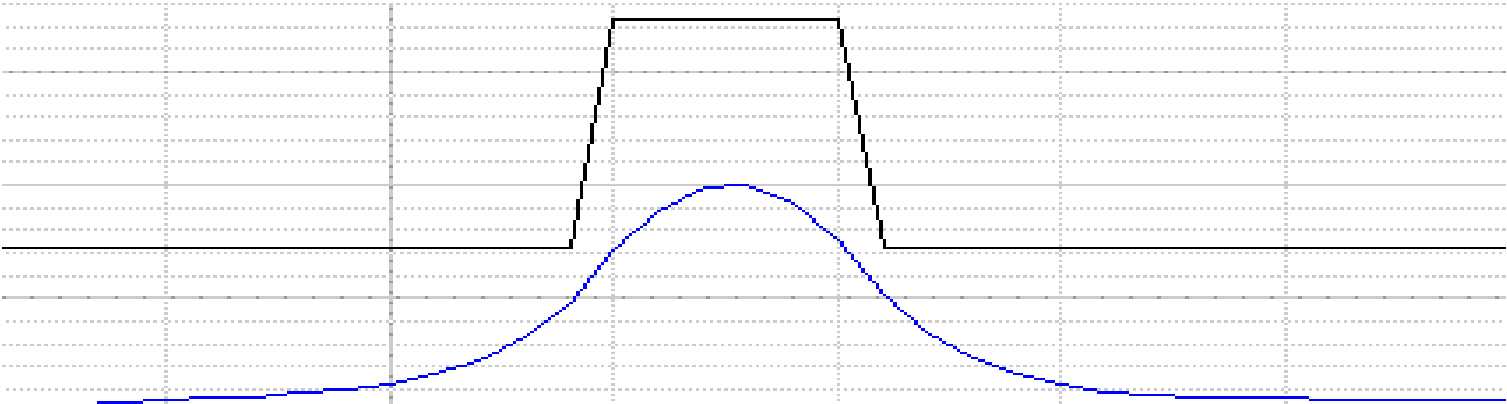
adm5,mrc7,
cjf4,ibm2,
10-26-04

Crosscut of the Rings with Different Δn

$\Delta n = 1$



$\Delta n = 2$



Frequency resolution and switch speed

Quality factor

$$Q = ? \text{ (Energy stored)/(Power loss)}$$

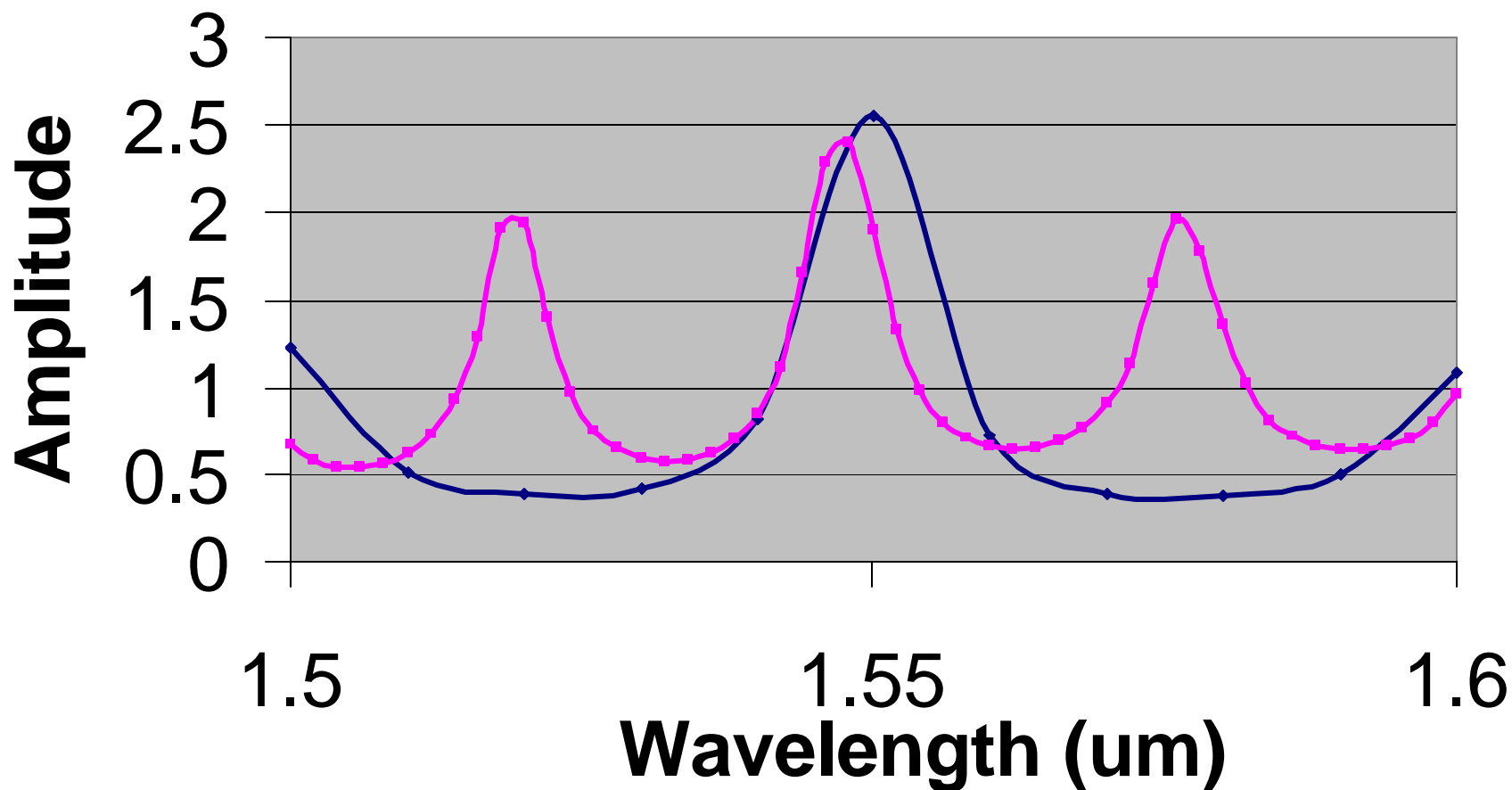
- High Q for narrow band filtering
 - Minimize loss; low loss and high energy
 - Maximize ave n for high stored energy
 - Tight coupling reduces length spread
- High switch speed
 - Low Q avoids excessive time constant Q/ω

Energy stored in microring resonator

$$\frac{1}{2} n^2 E^2 (\text{Volume})$$

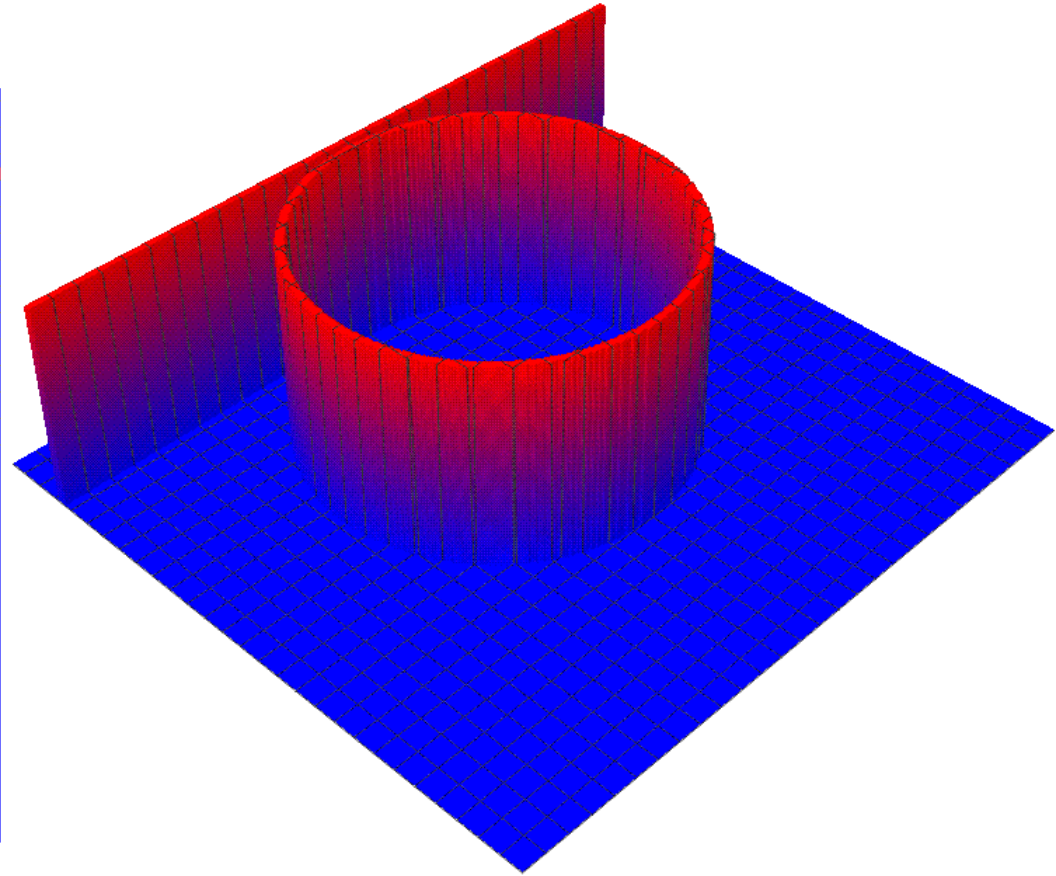
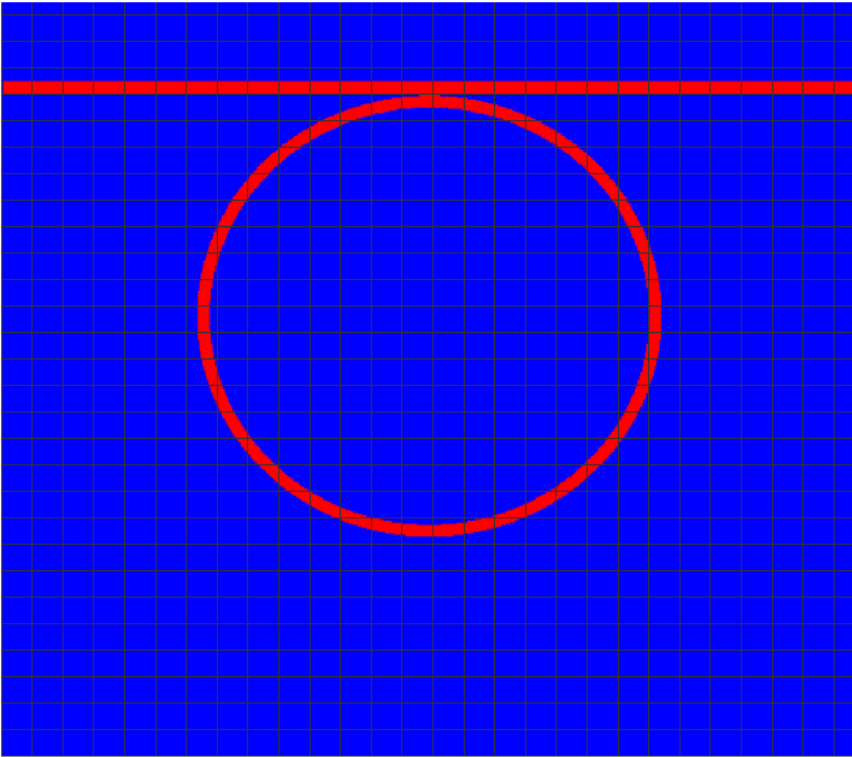
- High energy
 - Narrow filters, enhance nonlinearity and gain
- Volume increases with radius
- Refractive index
 - Use high n and high contrast Δn materials
- Ring loss
 - Minimize ring loss; reduces coupling to ring allowing many cycles to build up

Max Amplitude Vs. Wavelength



—•— Radius = 1.8um —+— Radius = 3.6um

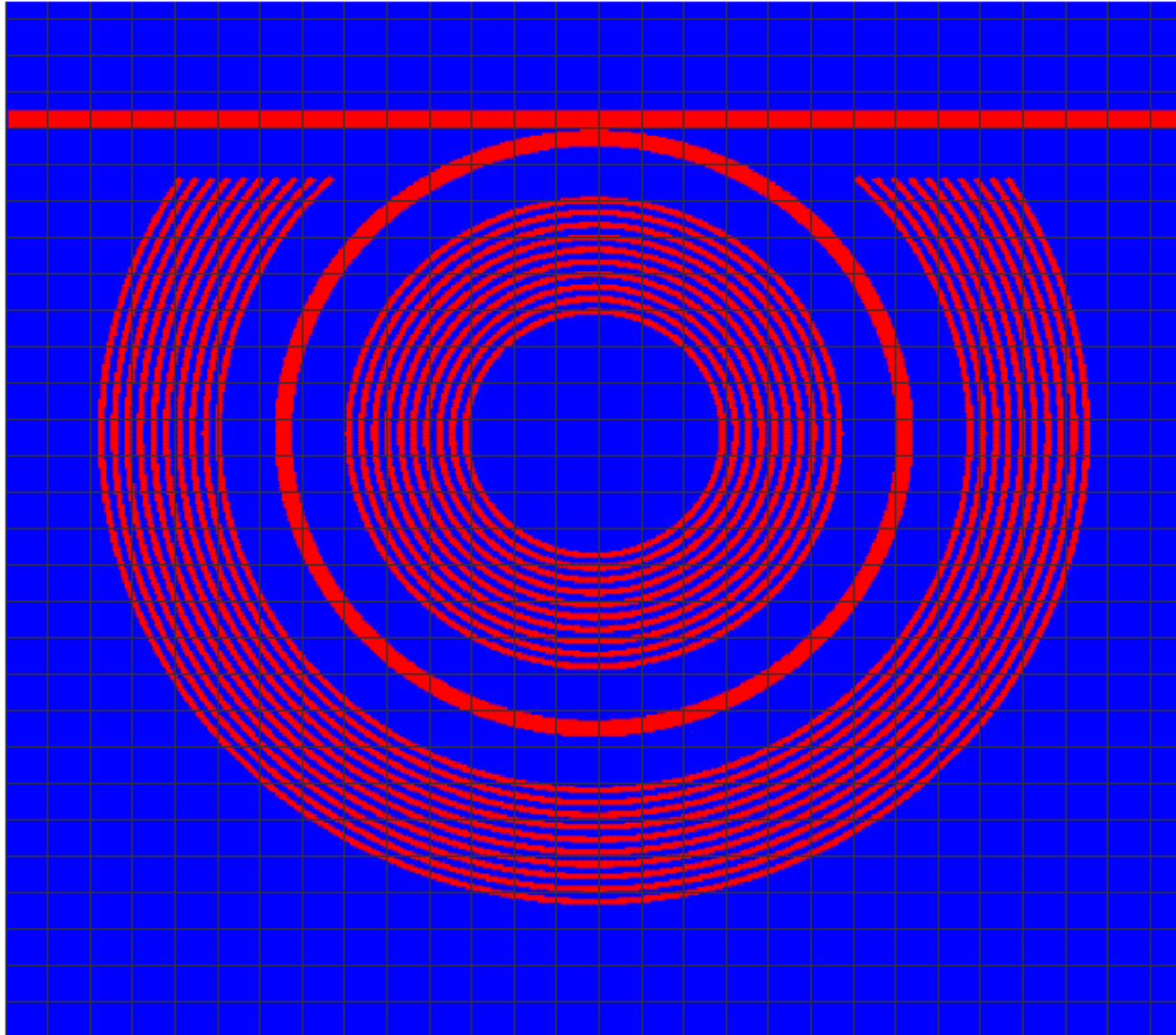
Layout of a Single Ring Resonator



Radius = 18.5 μ m

adm5,mrc7,cjf4,ibm2, 10-26-04

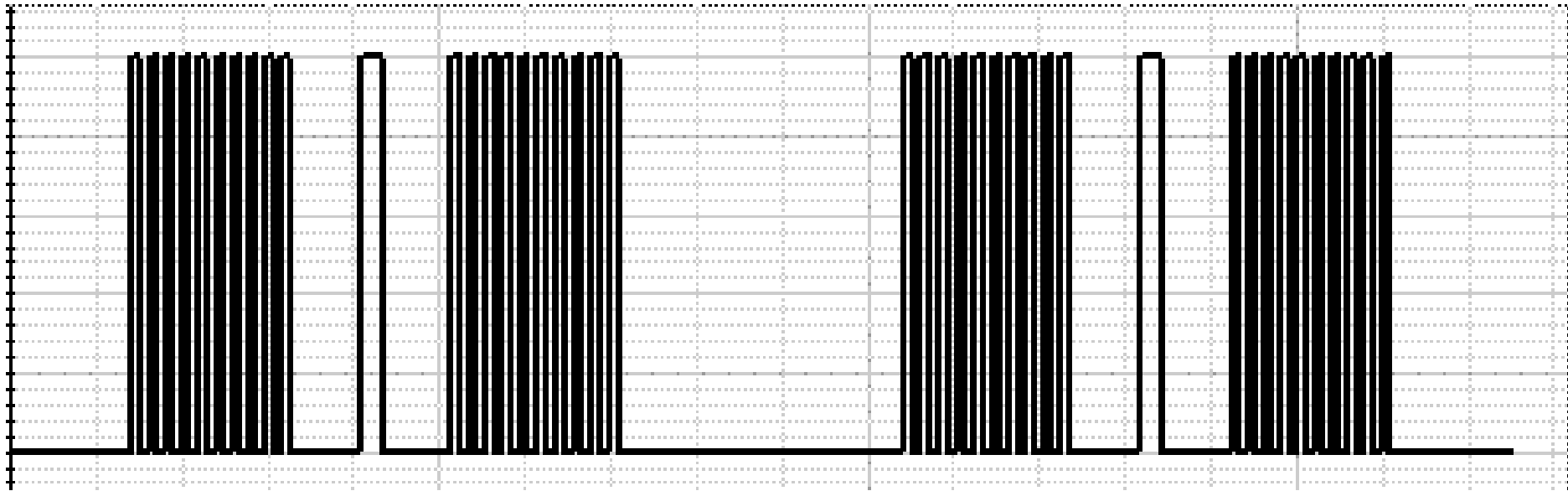
Layout of Ring Resonator with 10 Bragg Rings



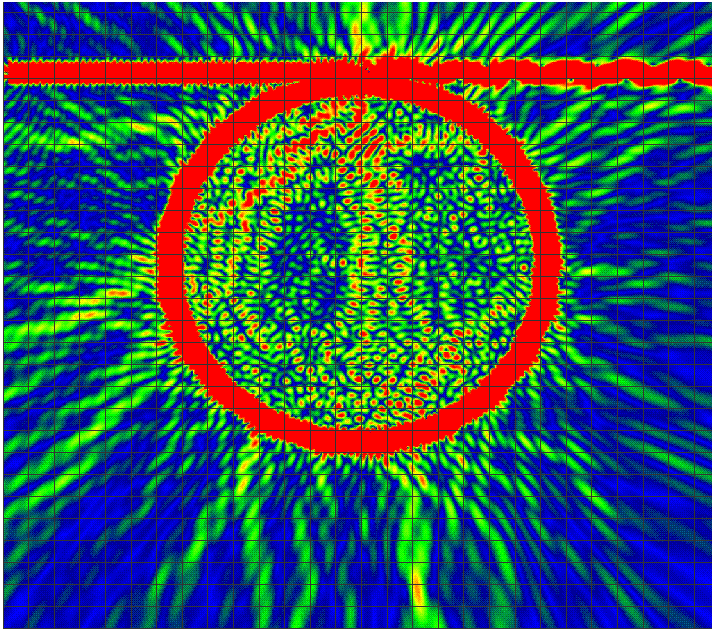
Radius =
18.5 μ m

adm5,mrc7,
cjf4,ibm2,
10-26-04

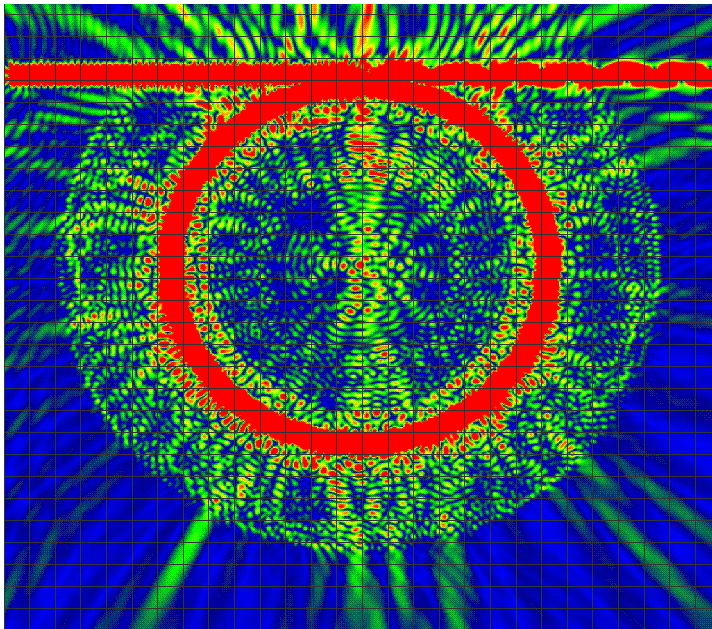
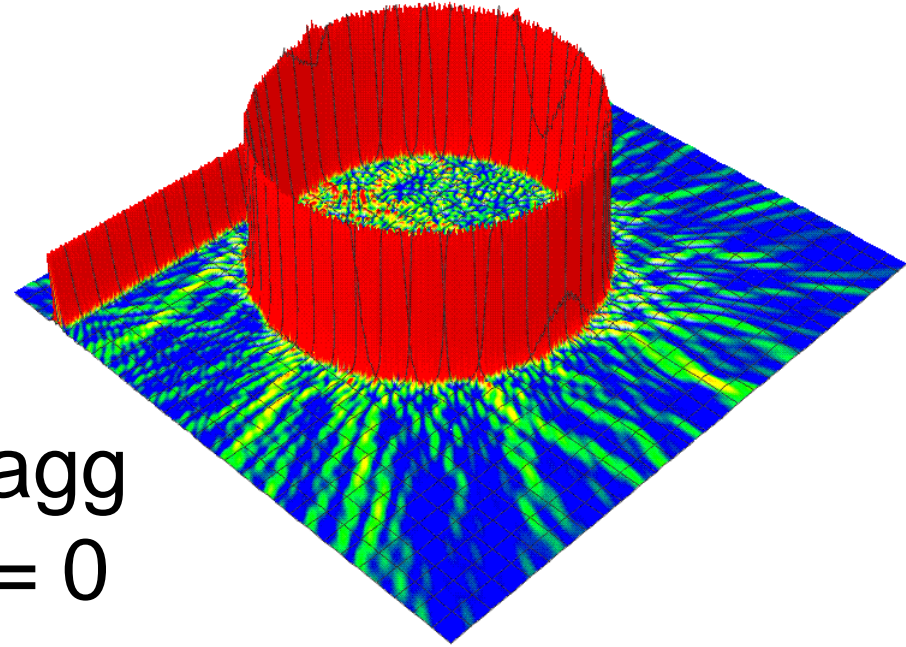
Crosscut of the Rings with 10 Bragg Rings



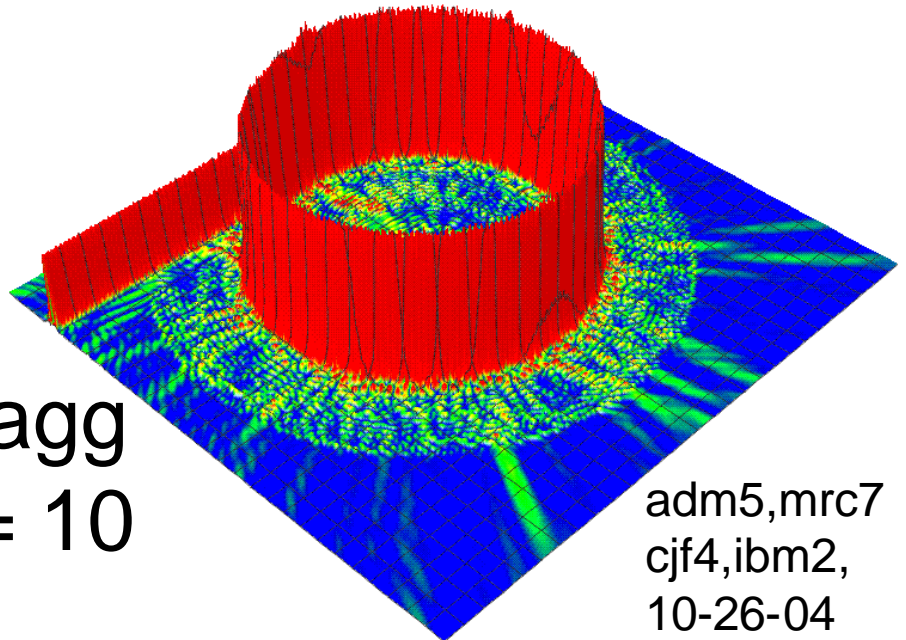
Loss of a Ring Depends on Number of Bragg Rings



of Bragg
Rings = 0

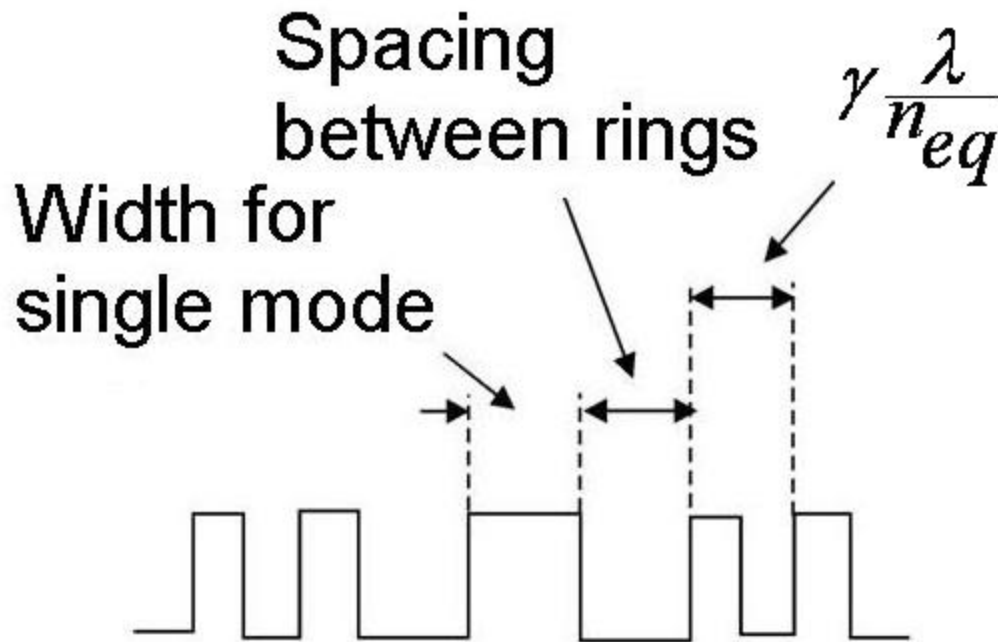


of Bragg
Rings = 10



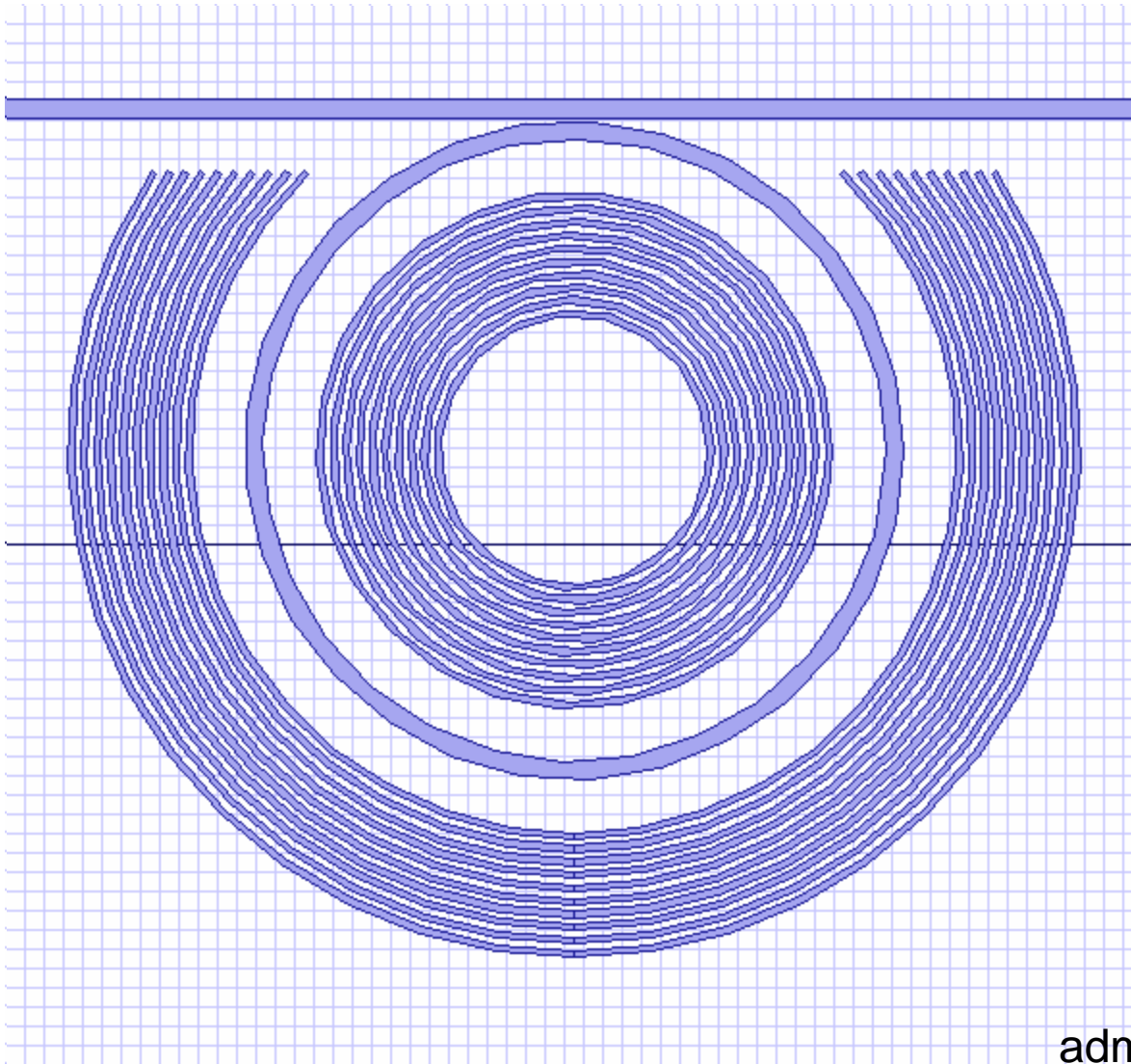
adm5,mrc7
cjf4,ibm2,
10-26-04

Layout with Bragg rings



- Bragg reflection spacing based on a straight waveguide needs to be altered
- Leakage from circular waveguide is at an angle, so the Bragg ring spacing should be changed to compensate

Different layouts of Bragg rings



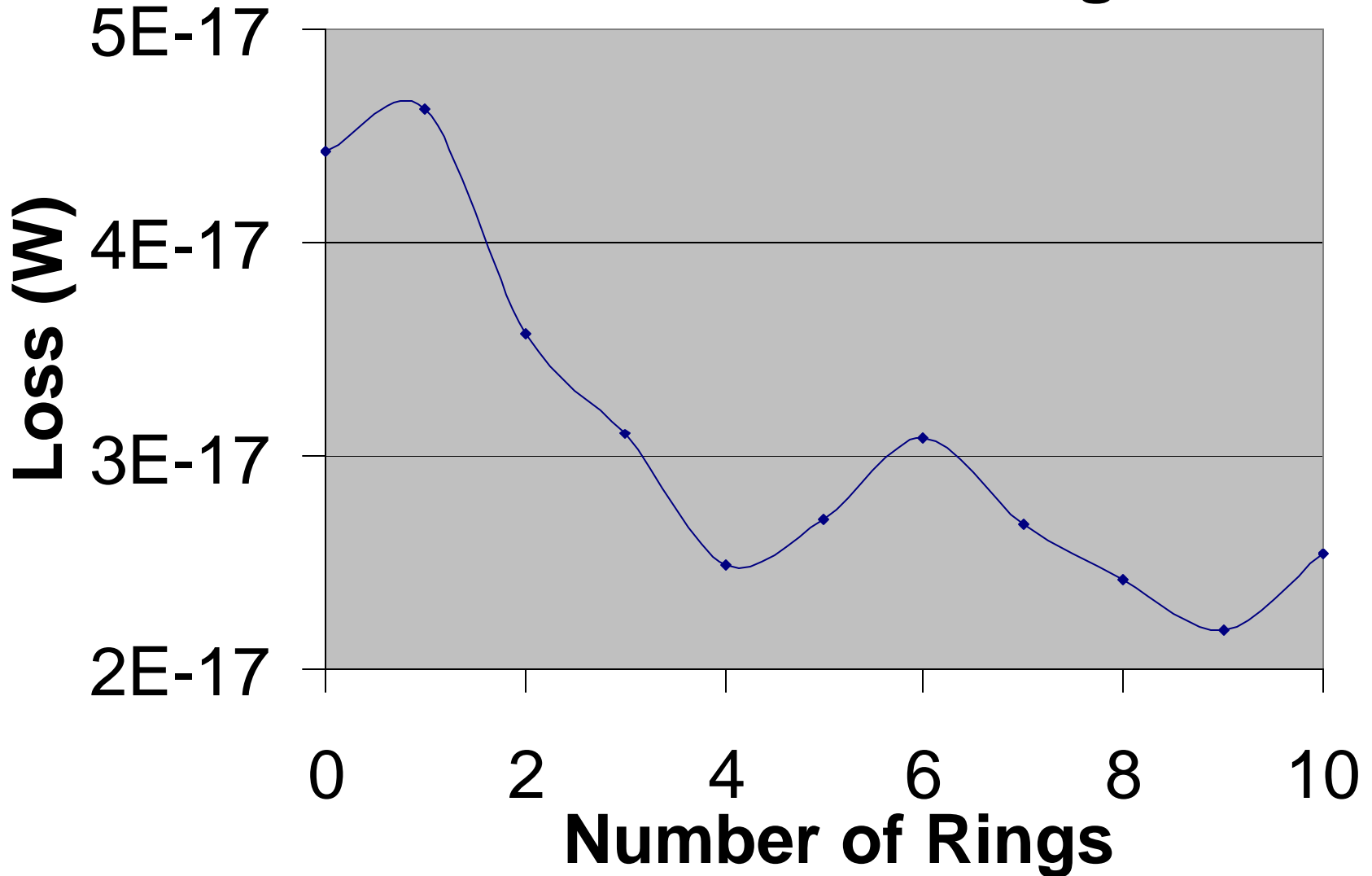
Starting configuration

First ring distance
decreased

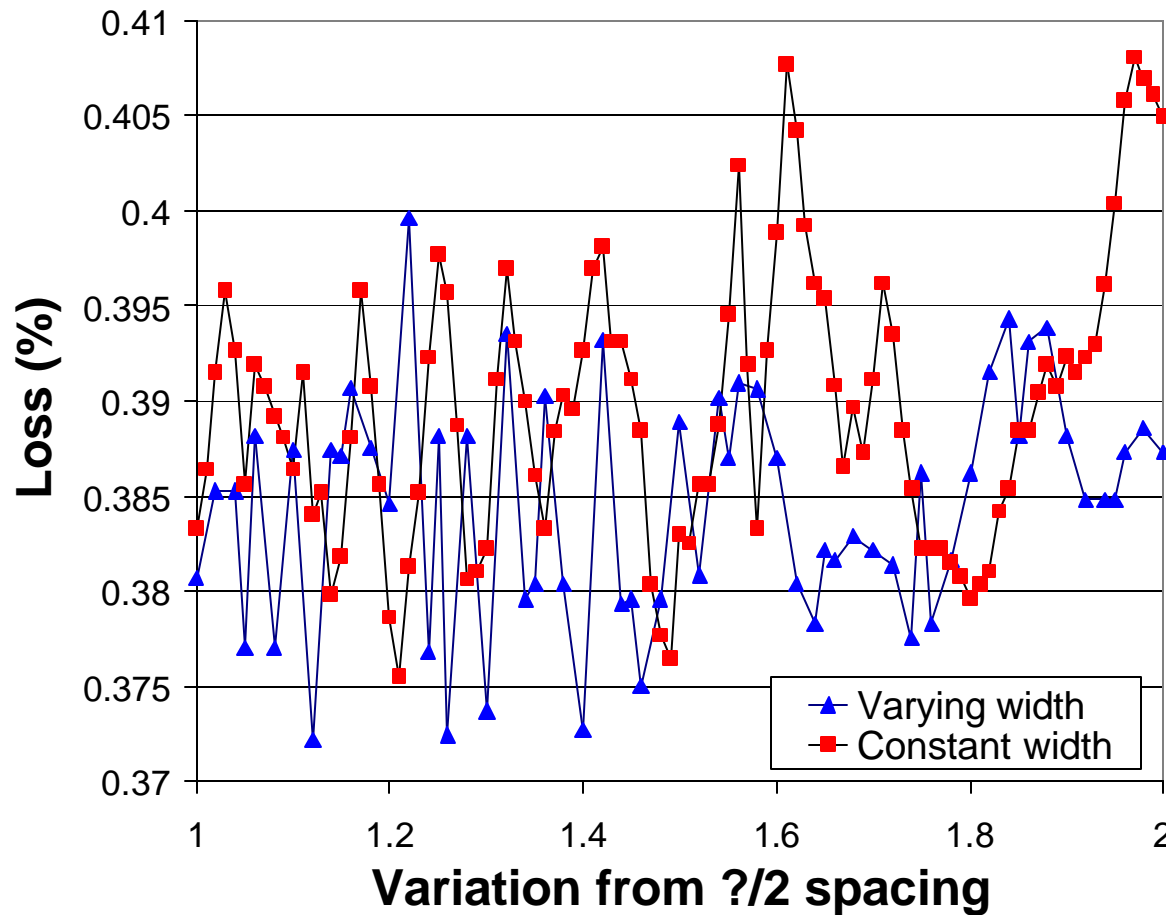
Ring spacing increased
(constant width)

Ring spacing decreased
(varying width)

Loss Vs. Number of Rings



Varying Bragg Grating Spacings



Loss can be minimized using a width corresponding to the variation from $\lambda/2$ spacing

Results indicate that tangential energy leakage results in wider choice of ring spacing

Conclusion

- Microring resonator
 - Structure and operation as filter described
 - Showed loss variation with size and n
 - Showed trade-offs for energy, size and Q
- Bragg reflector microring
 - Showed reduced loss with Bragg rings
 - Analyzed optimum ring structure