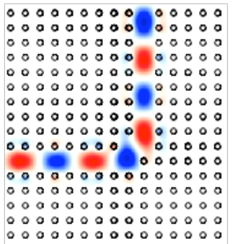
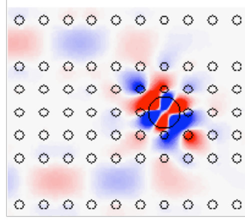
“1d” Waveguides + Cavities = Devices

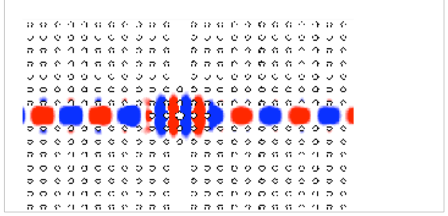
high transmission through sharp bends



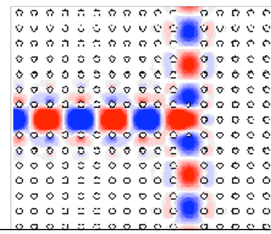
channel-drop filter



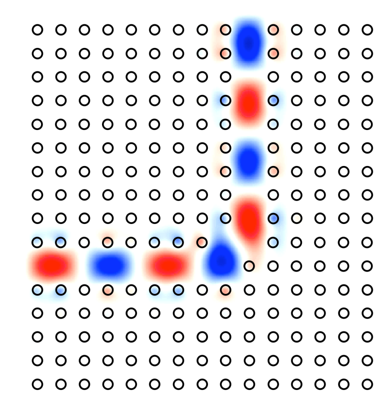
elimination of waveguide crosstalk



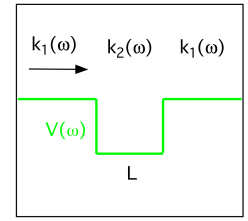
high transmission in wide-angle splitters



Lossless Bends



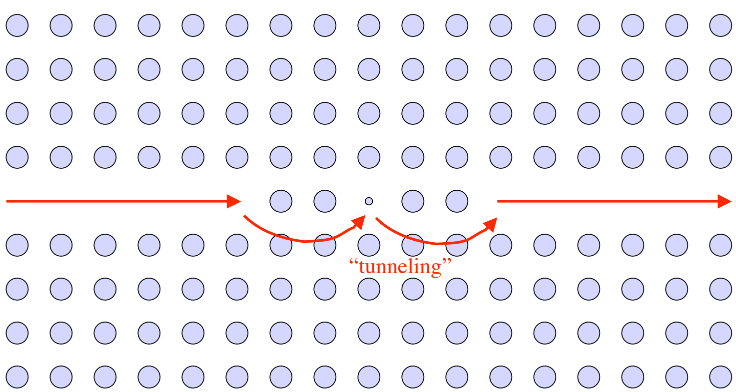
Maps onto problem of Electron Resonant Scattering in 1D



[A. Mekis *et al.*, *Phys. Rev. Lett.* **77**, 3787 (1996)]

symmetry + single-mode + “1d” = resonances of 100% transmission

Waveguides + Cavities = Devices

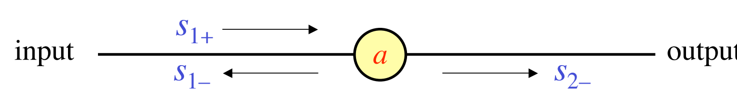


Ugh, must we simulate this to get the basic behavior?

“Coupling-of-Modes-in-Time”

(a form of coupled-mode theory)

[H. Haus, *Waves and Fields in Optoelectronics*]



resonant cavity

frequency ω_0, lifetime τ

$|s|^2$ = flux

$|a|^2$ = energy

$$\frac{da}{dt} = -i\omega_0 a - \frac{2}{\tau} a + \sqrt{\frac{2}{\tau}} s_{1+}$$

$$s_{1-} = -s_{1+} + \sqrt{\frac{2}{\tau}} a, \quad s_{2-} = \sqrt{\frac{2}{\tau}} a$$

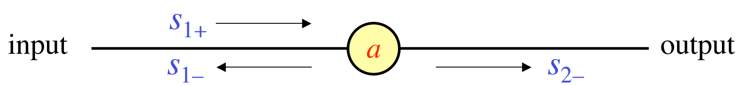
assumes only:

- exponential decay (strong confinement)
- conservation of energy
- time-reversal symmetry

“Coupling-of-Modes-in-Time”

(a form of coupled-mode theory)

[H. Haus, *Waves and Fields in Optoelectronics*]

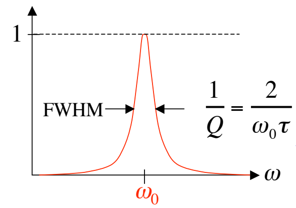


resonant cavity
frequency ω_0, lifetime τ

$|s|^2$ = flux

$|a|^2$ = energy

transmission T
$= | s_{2-} |^2 / | s_{1+} |^2$



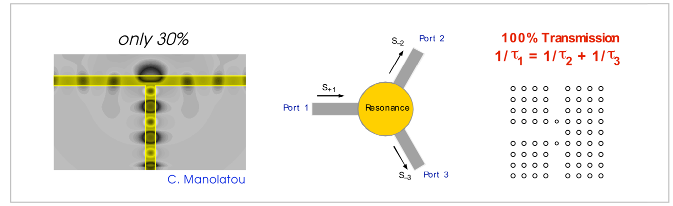
$$\frac{1}{Q} = \frac{2}{\omega_0 \tau}$$

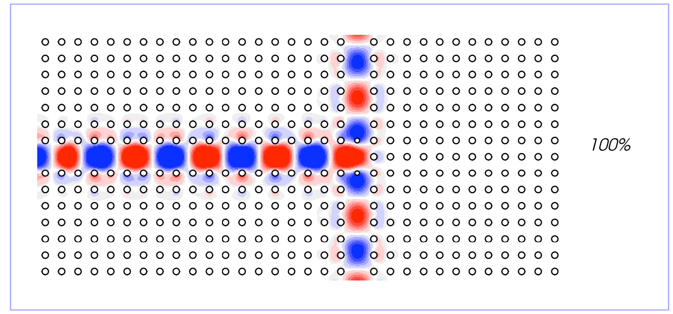
T = Lorentzian filter

$$= \frac{\frac{4}{\tau^2}}{(\omega - \omega_0)^2 + \frac{4}{\tau^2}}$$

…quality factor Q

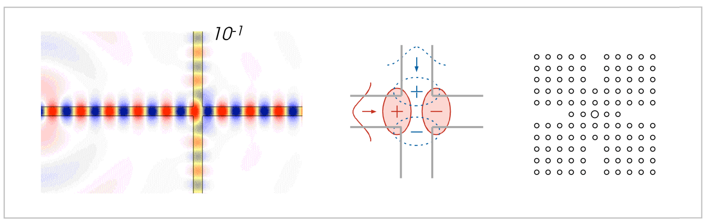
Wide-angle Splitters

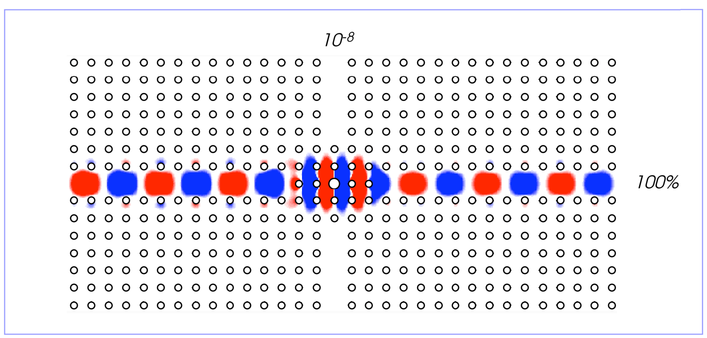




[S. Fan *et al.*, *J. Opt. Soc. Am. B* **18**, 162 (2001)]

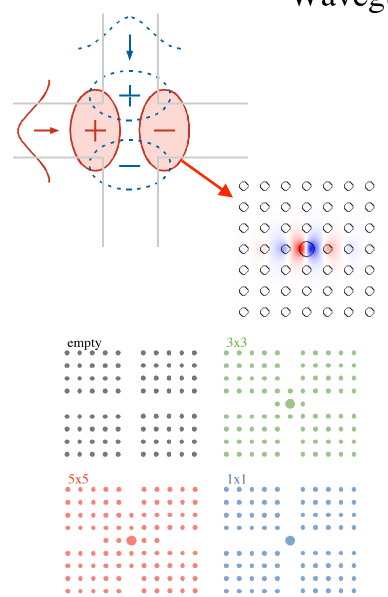
Waveguide Crossings

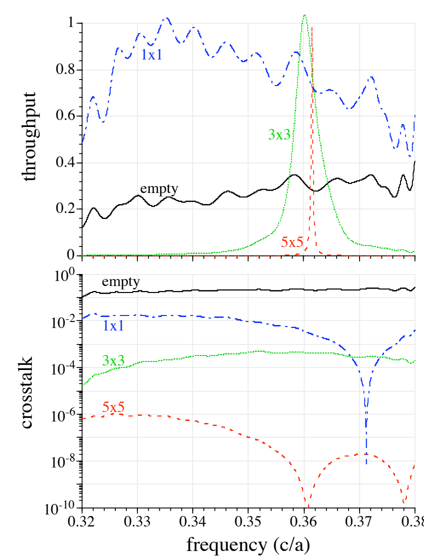




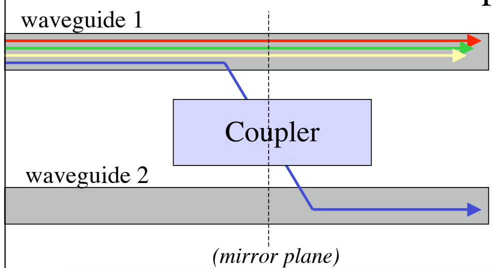
[S. G. Johnson *et al.*, *Opt. Lett.* **23**, 1855 (1998)]

Waveguide Crossings





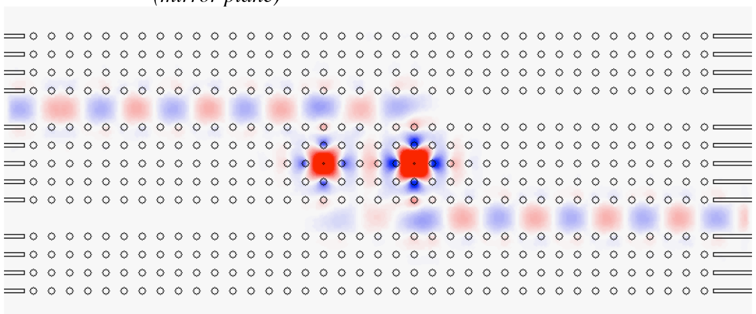
Channel-Drop Filters



Perfect channel-dropping if:

Two resonant modes with:

- even and odd symmetry
- equal frequency (degenerate)
- equal decay rates



[S. Fan *et al.*, *Phys. Rev. Lett.* **80**, 960 (1998)]

Enough passive, linear devices…

Photonic crystal cavities:

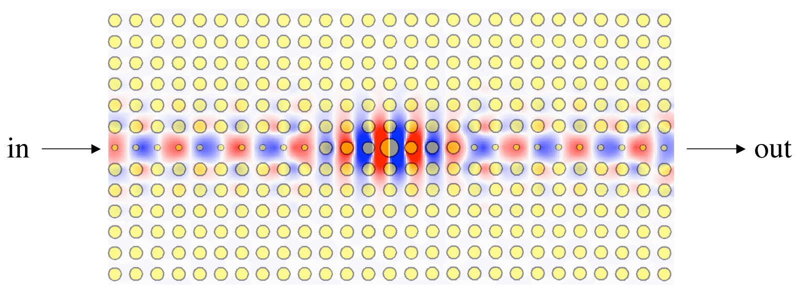
tight confinement (~ $\lambda/2$ diameter)

+ long lifetime (high Q independent of size)

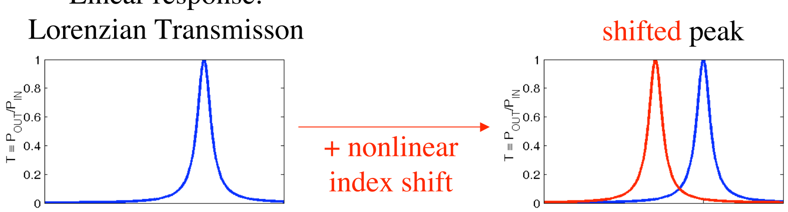
= enhanced nonlinear effects

e.g. Kerr nonlinearity, Δn ~ intensity

A ~~Linear~~ *Nonlinear* Filter

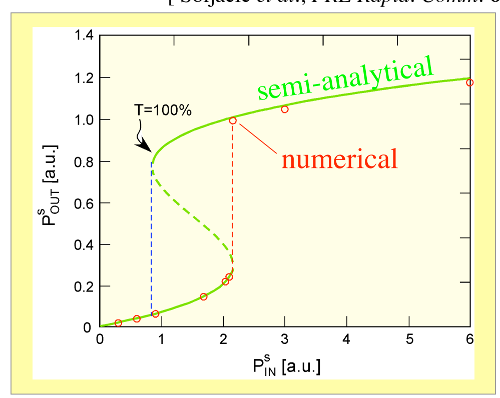


Linear response:
Lorenzian Transmisson



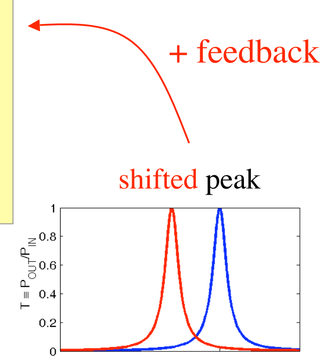
A ~~Linear~~ *Nonlinear* "Transistor"

[Soljacic *et al.*, *PRE Rapid. Comm.* **66**, 055601 (2002).]



Logic gates, switching, rectifiers, amplifiers, isolators, …

+ feedback

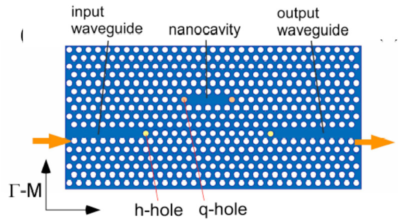


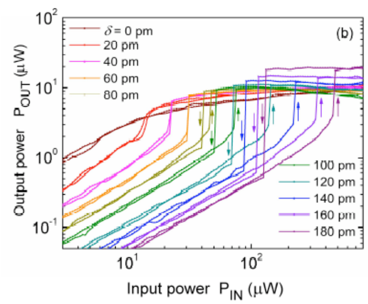
Bistable (hysteresis) response

Power threshold ~ Q^2/V is near optimal
(~mW for Si and telecom bandwidth)

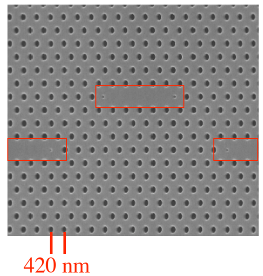
Experimental Bistable Switch

[Notomi *et al*., *Opt*. *Express* **13** (7), 2678 (2005).]





Silicon-on-insulator



Q ~ 30,000

Power threshold ~ 40 μW

Switching energy ~ 4 pJ