METAMATERIALS & PHOTONICS

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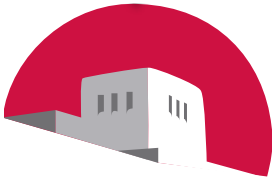
EPSRC

Engineering and Physical Sciences Research Council

Science & Technology Facilities Council

University of HUDDERSFIELD
Inspiring tomorrow's professionals



University of Strathclyde Glasgow

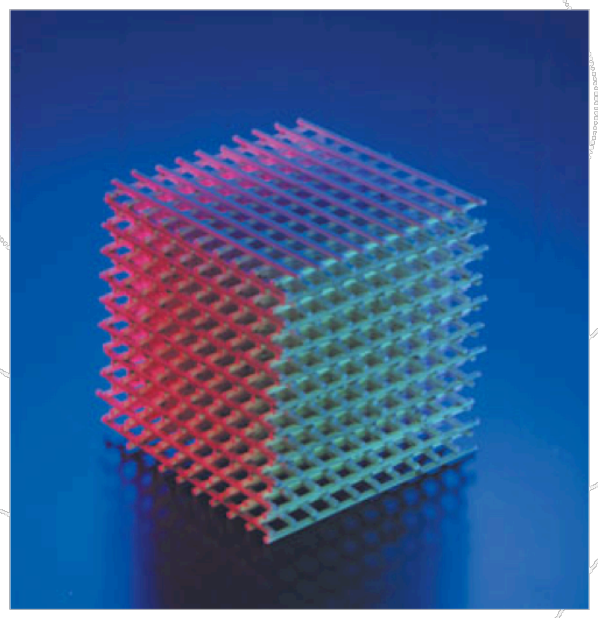
LSU

THE OHIO STATE UNIVERSITY

UNIVERSITY of CALIFORNIA · IRVINE

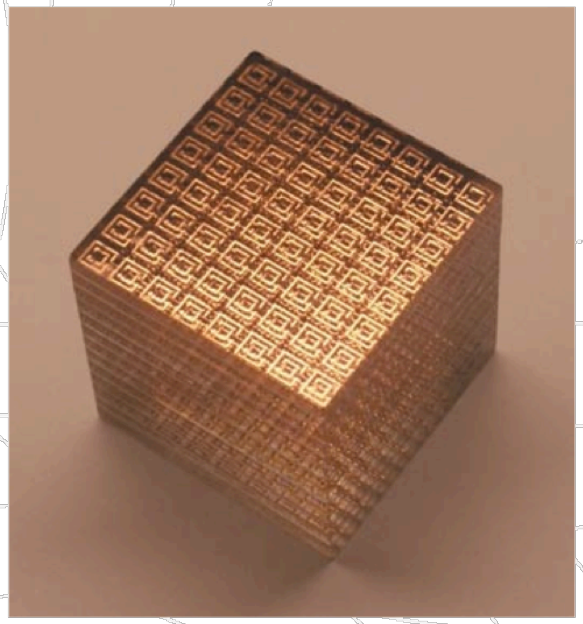
PSFC Plasma Science & Fusion Center @ MIT

Photonic



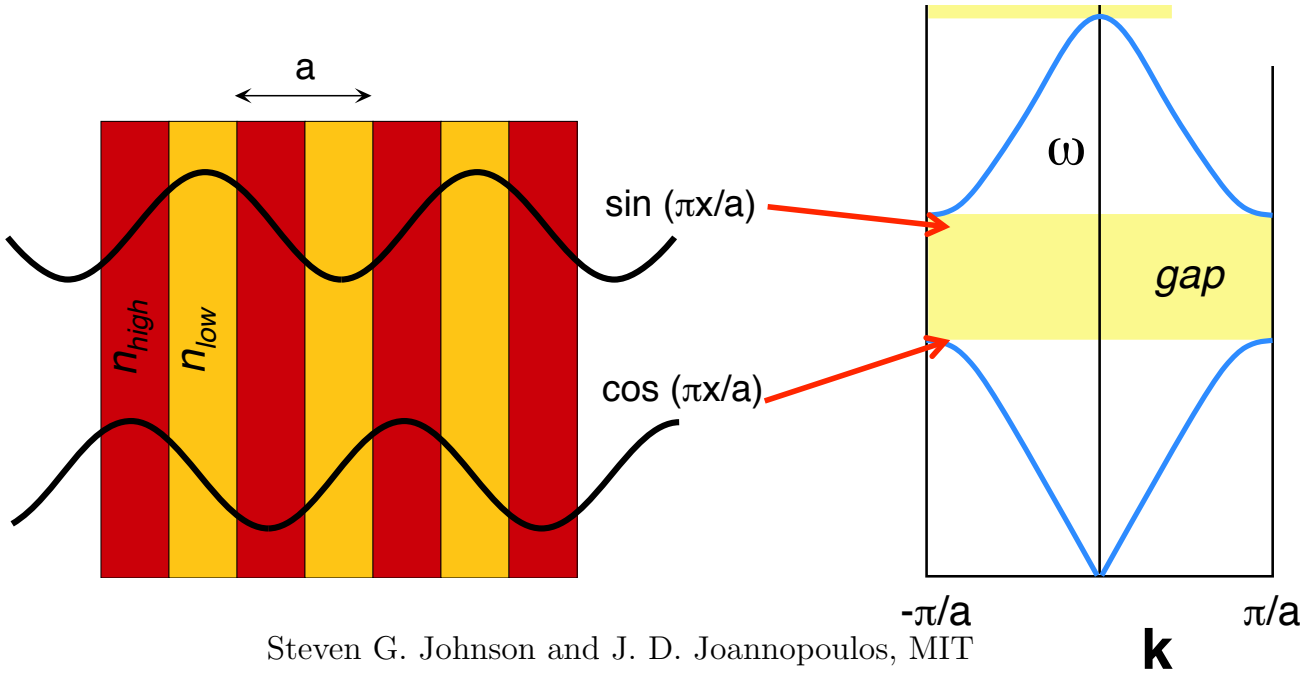
$a \sim \lambda$

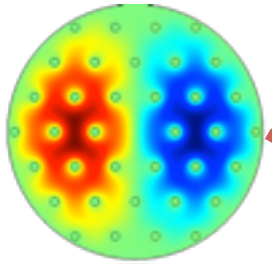
Metamaterial

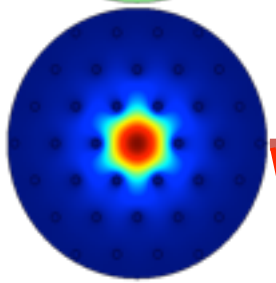


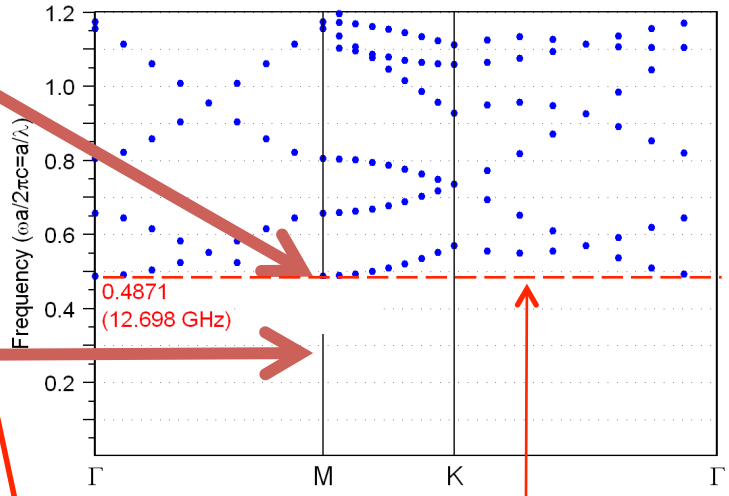
$a << \lambda$

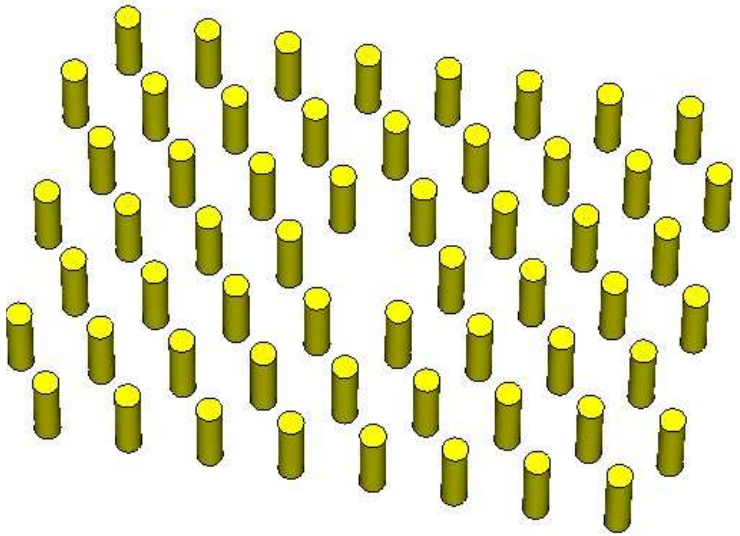
$$(\vec{\nabla} + i\vec{k}) \times \frac{1}{\varepsilon}(\vec{\nabla} + i\vec{k}) \times \vec{H}_{n,\vec{k}} = \left(\frac{\omega_n(\vec{k})}{c}\right)^2 \vec{H}_{n,\vec{k}},$$





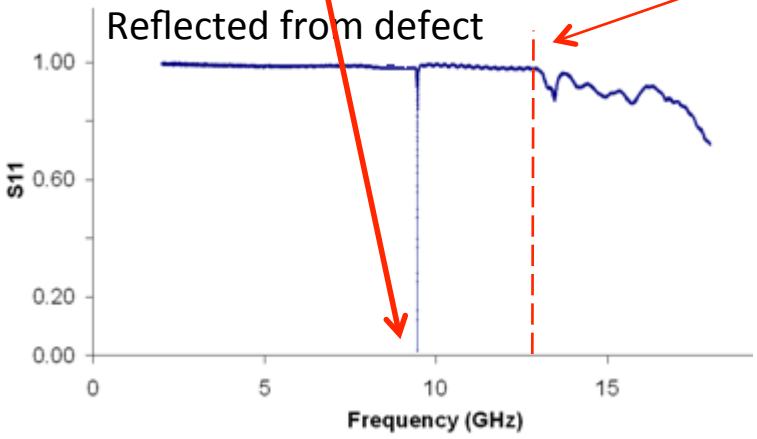




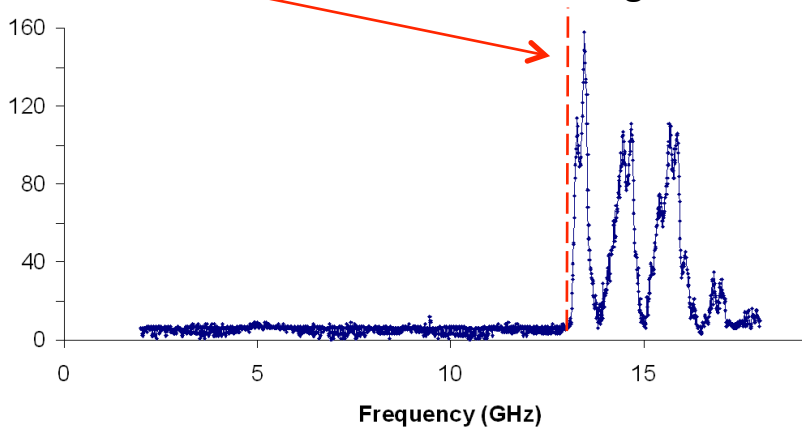


(12.698 GHz)

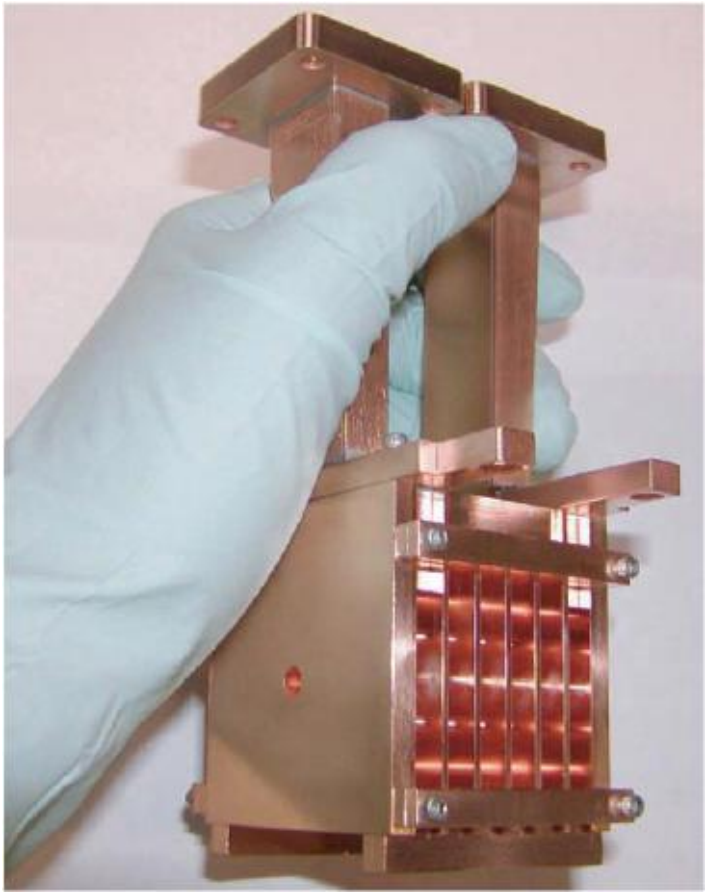
Reflected from defect



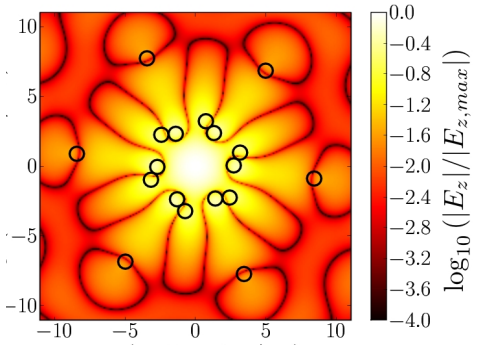
Power through lattice



- Experimental results validate concept
- Demonstrated acceleration at 17 GHz at MIT (Smirnova 2005)
  - 35 MV/m achieved
- High-power testing at SLAC at 11 GHz (Marsh 2009)
  - 100 MV/m achieved
  - Showed influence of high H fields on breakdown



- E. I. Smirnova, A. S. Kesar, I. Mastovsky, M. A. Shapiro and R. J. Temkin,Phys. Rev. Lett., 95, 074801, 2005
- R. A. Marsh, M. A. Shapiro, R. J. Temkin, E. I. Smirnova and J. F. DeFord, Nucl. Instrum. Methods Phys. Res., Sect. A 618, 16, 2010.

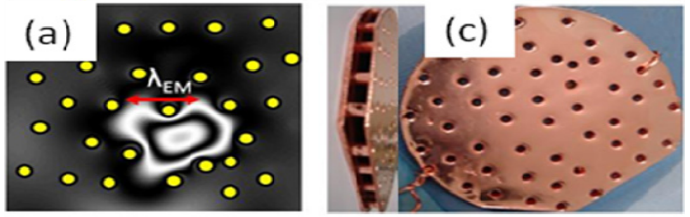


Truncated photonic crystal

Gregory R. Werner, Carl A. Bauer, John R. Cary,
Phys. Rev. ST – AB, 12, 071301 (2009)

$Q_0 = 10^4$

Anderson Localization



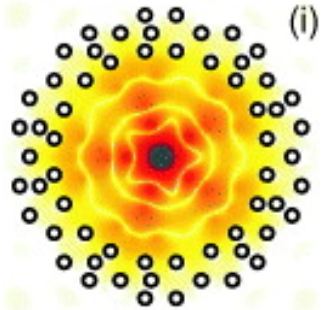
R. Seviour and A. Oladipo, IPAC'10 (2010)

$Q_0 = 10^9$

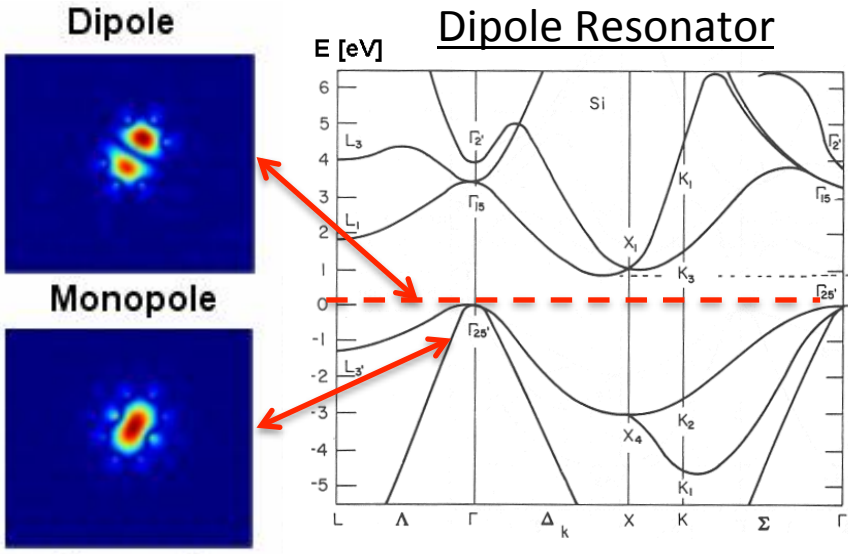
Penrose Lattice

E. Gennaro, et. al.,
New J. Phys. **11** (2009) 113022

$Q_0 = 10^8$



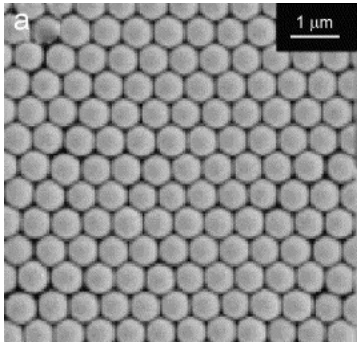
Dipole Resonator

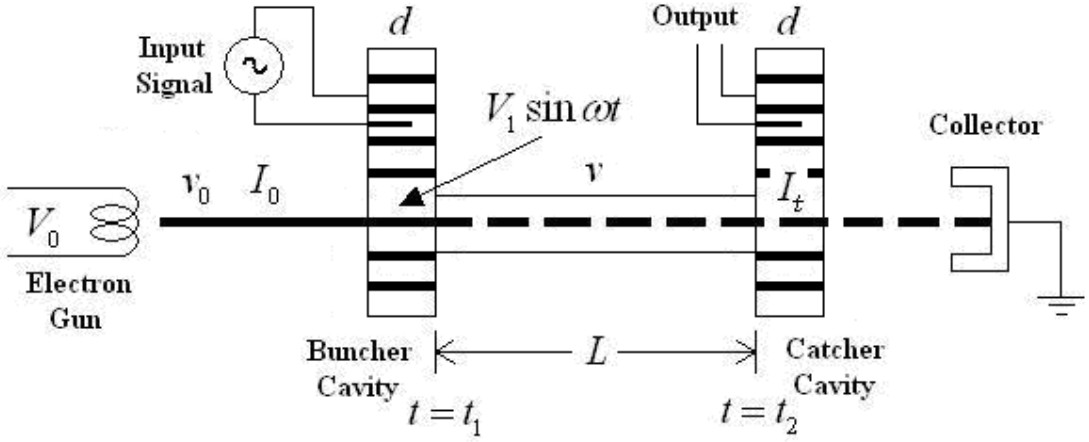


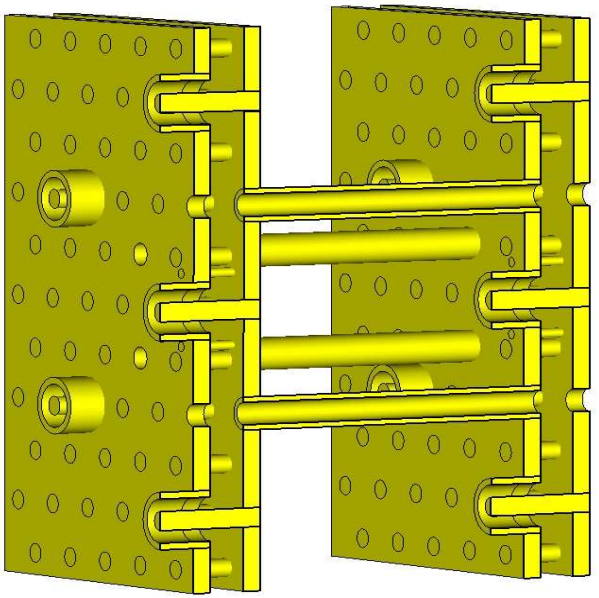
Whispering Gallery mode Microsphere

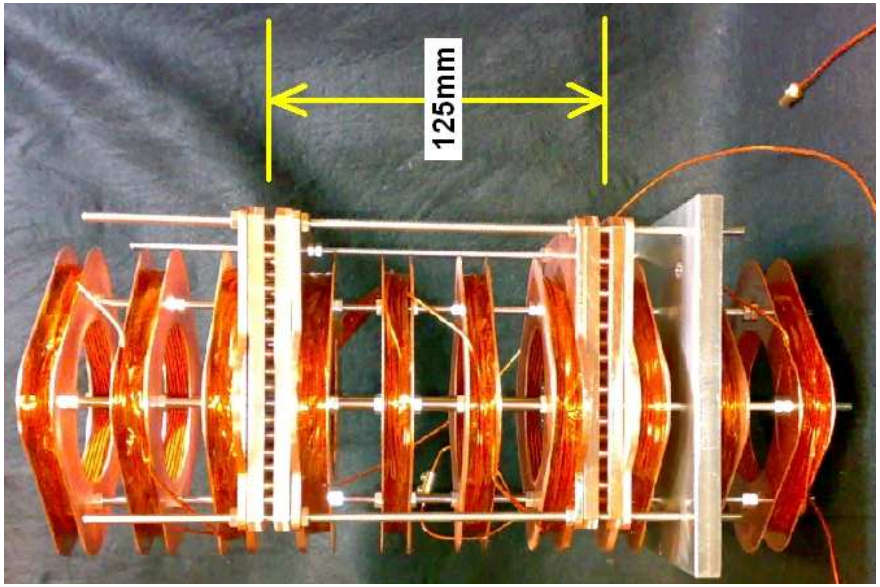
M. L. Gorodetsky, A. A. Savchenkov, and V. S. Ilchenko,
Optics Letters, Vol. 21, Issue 7, pp. 453-455 (1996)

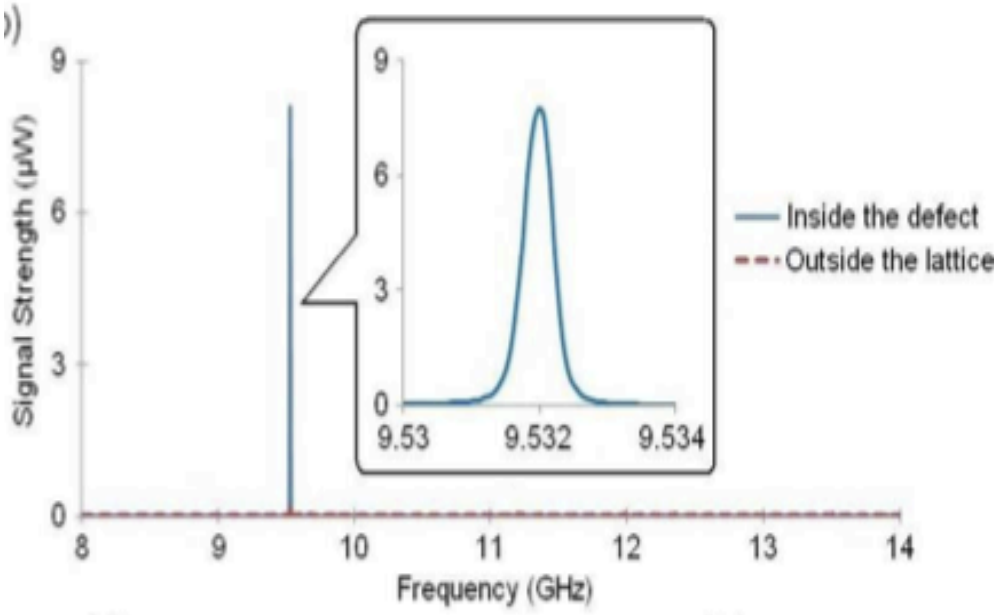
$Q_0 = 10^{10}$





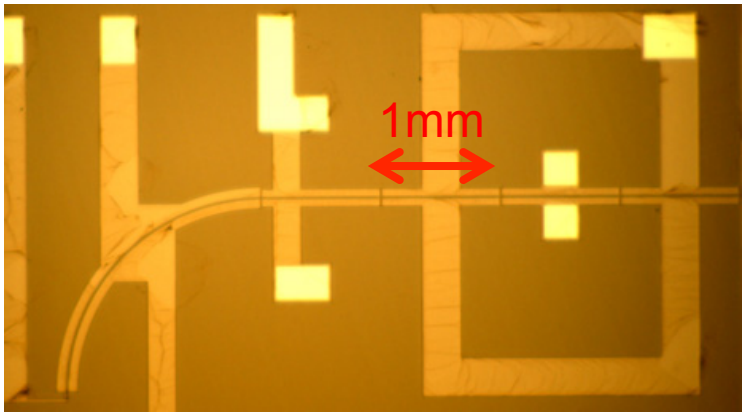






Y Xu and R Seviour, *New J. Phys.* **14** 013014 (2012)

Dielectric Laser Accelerator Workshop
Sep 15th - 16th, 2011
SLAC National Accelerator Laboratory
Panofsky Auditorium
Menlo Park, CA



MEMS Ion Race Track

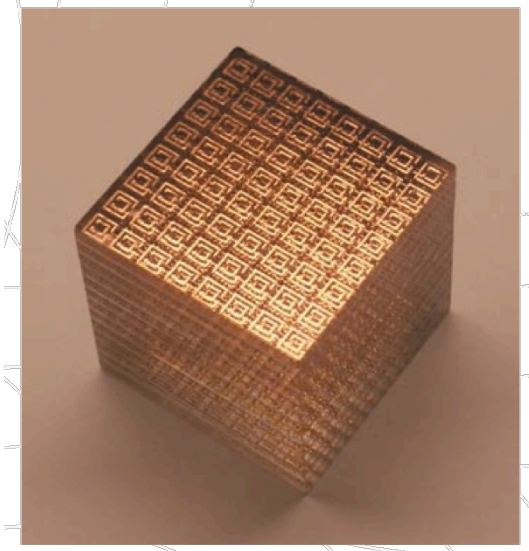
Yue Shi (2011)

Ar^+ accelerated to 2 KeV

Current aim is 2 MeV

http://spectrum.ieee.org/semiconductors/devices/engineers-unveil-particle-accelerator-on-a-chip

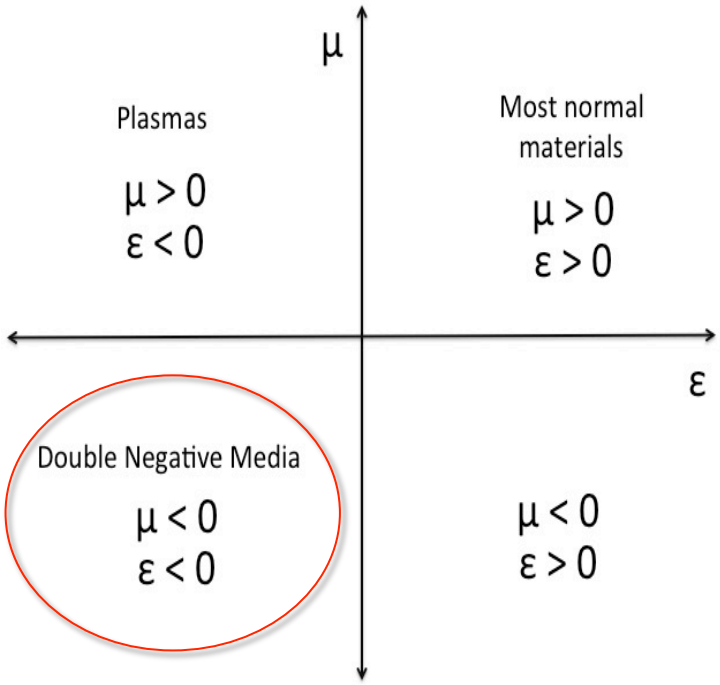
Metamaterial

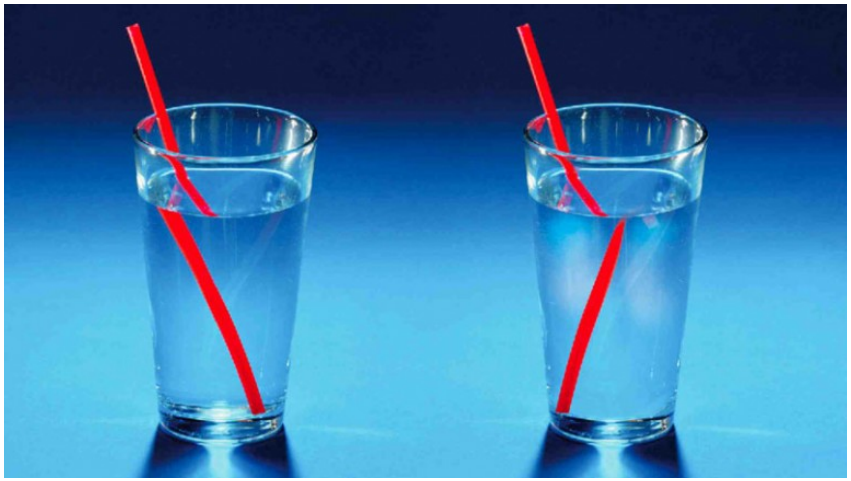


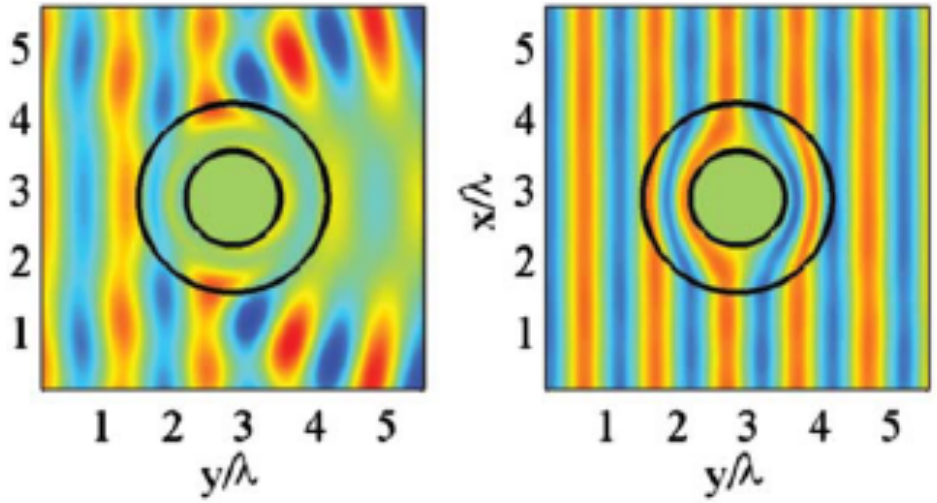
The term “Metamaterials” was first coined by Rodger Walser, as:

Macroscopic composites having man-made, three-dimensional, periodic cellular architecture designed to produce an optimized combination, not available in nature, of two or more Responses to specific excitation.

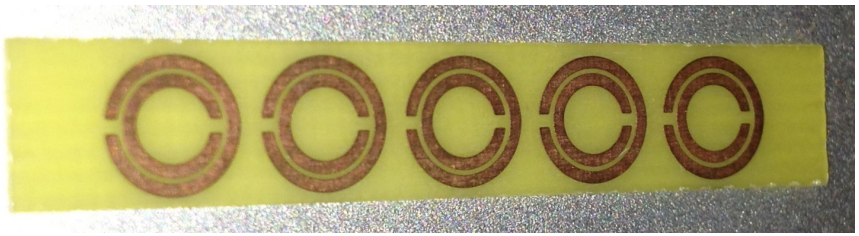
$a << \lambda$







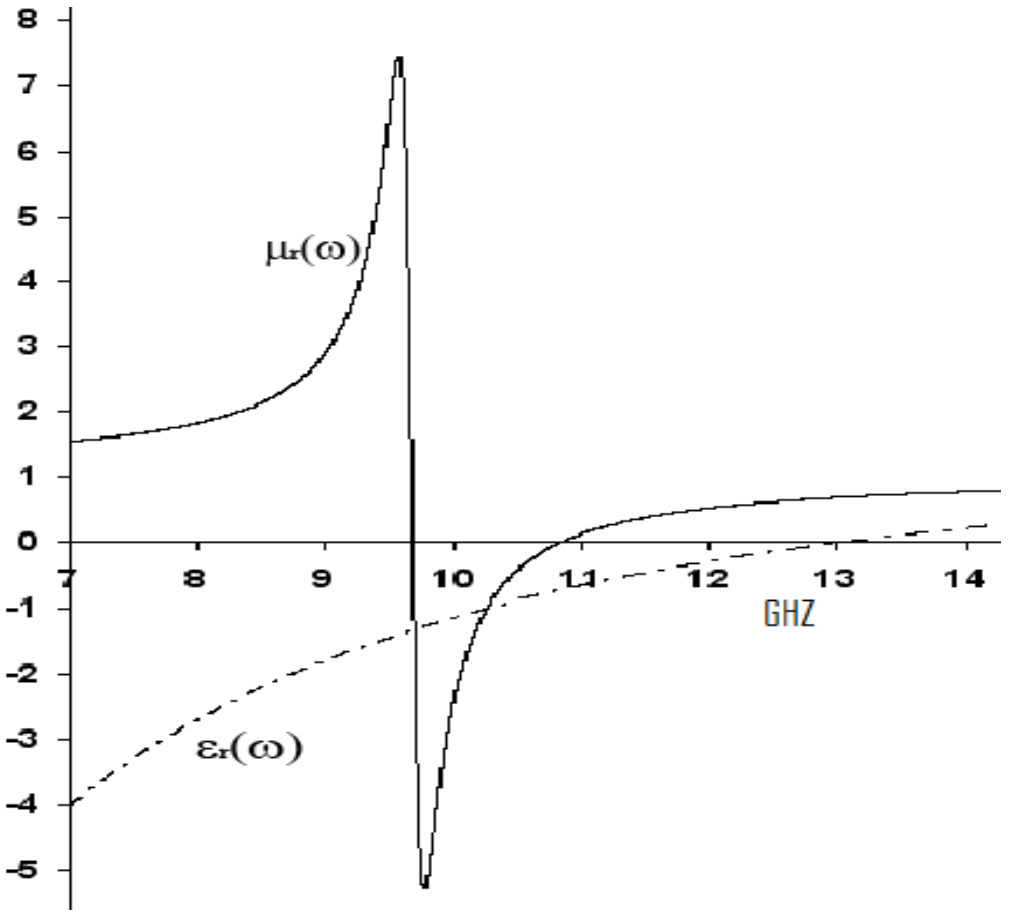
D. R. Smith, J. B. Pendry, and M. C. K. Wiltshire
Science 6 August 2004: **305** (5685), 788-792

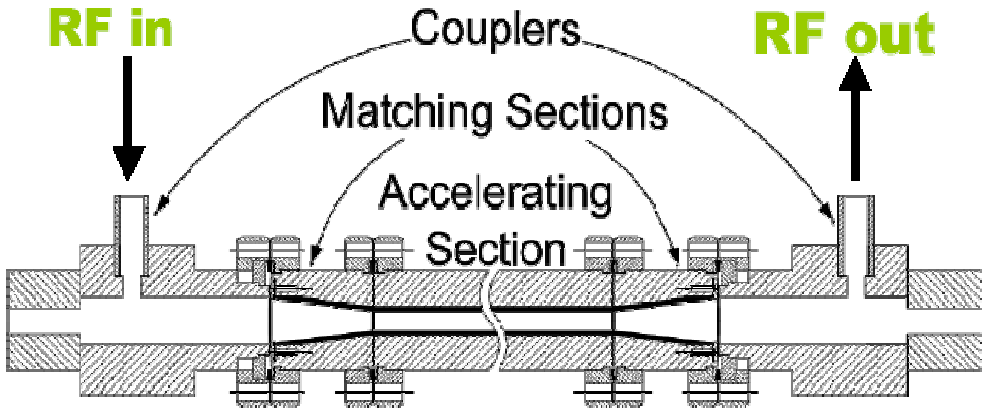


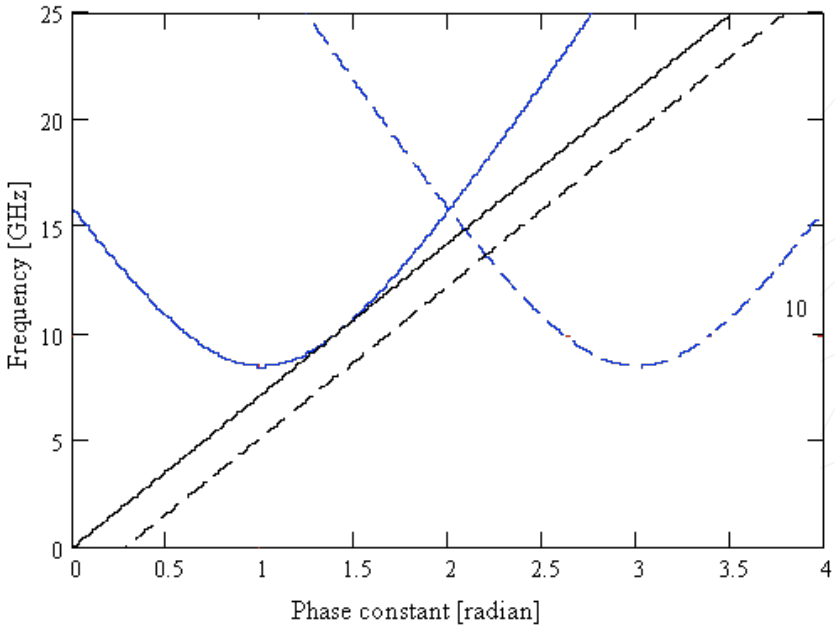
$$\hat{D} = \epsilon_0 \hat{E} + P = \epsilon \hat{E}$$
$$\hat{B} = \mu_0 \hat{H} + M = \mu \hat{H}$$

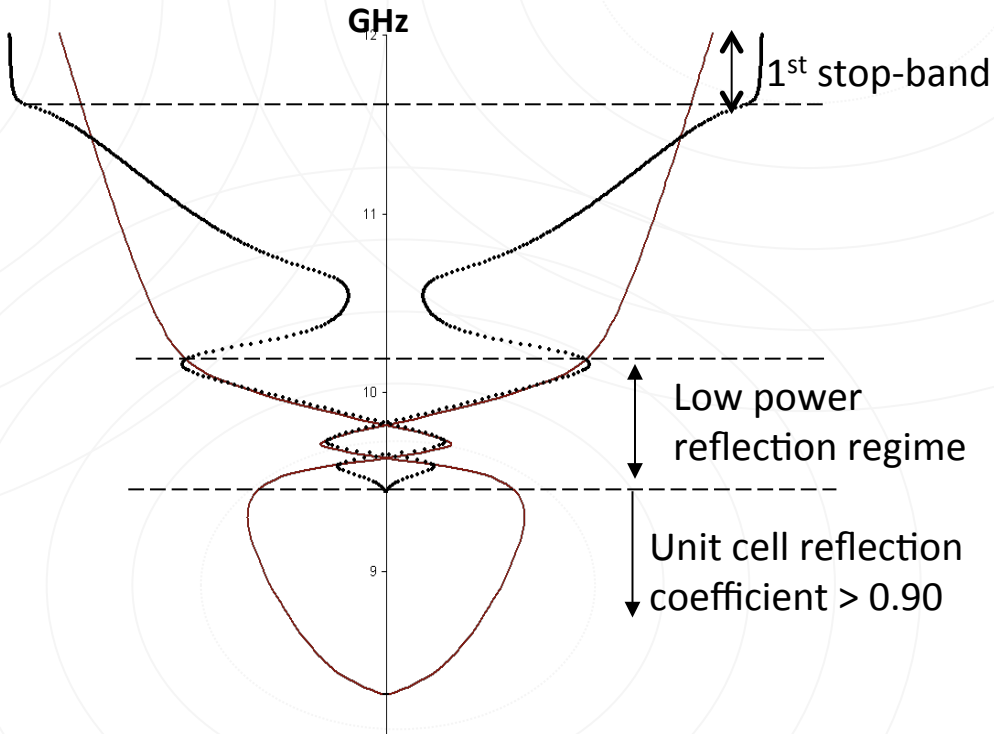
$$\epsilon_r(\omega) = \epsilon_\infty - \frac{\epsilon_\infty \omega_p^2}{\omega(\omega - i\nu_c)}$$

$$\mu_r(\omega) = \mu_\infty + \frac{(\mu_s - \mu_\infty)\omega_0^2}{\omega_0^2 - \omega^2 + i\omega\delta}$$

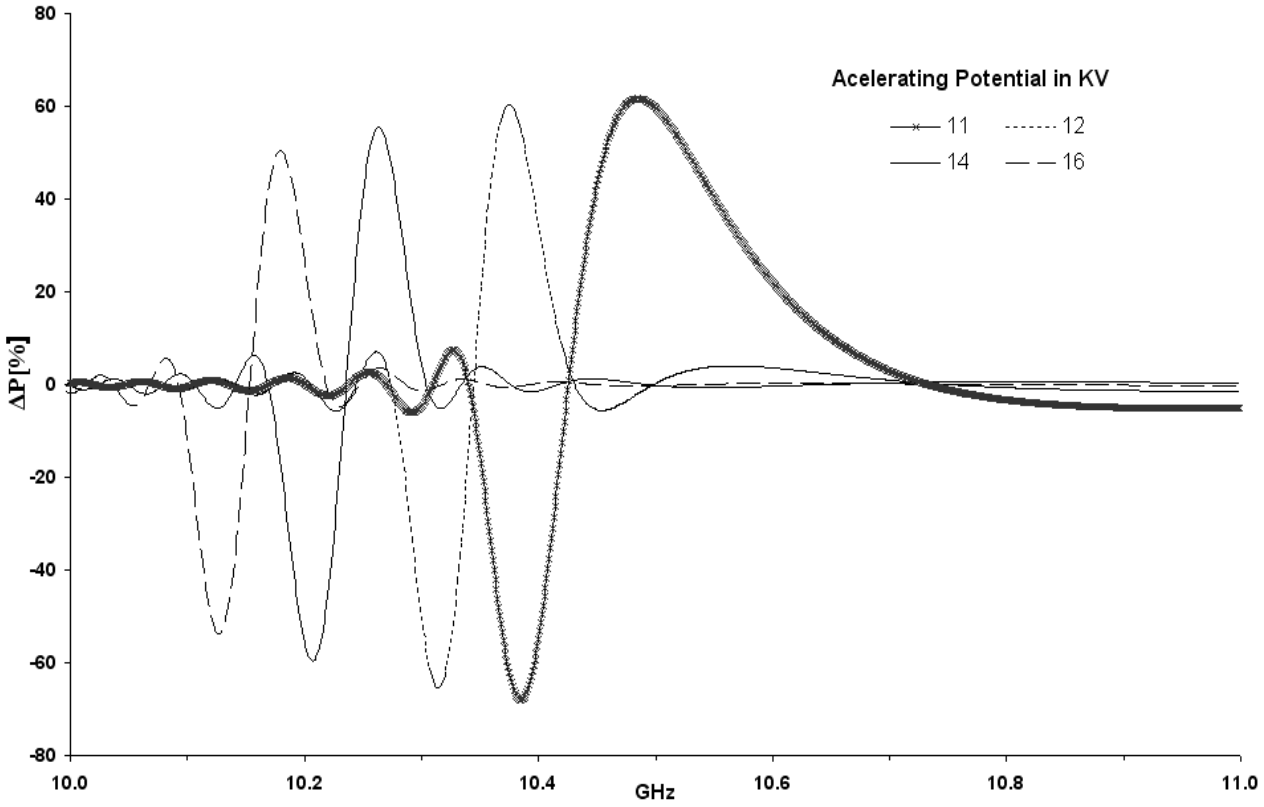








Y. S. Tan and R. Seviour,
Europhysics Letters, 87(3):34005, 2009.

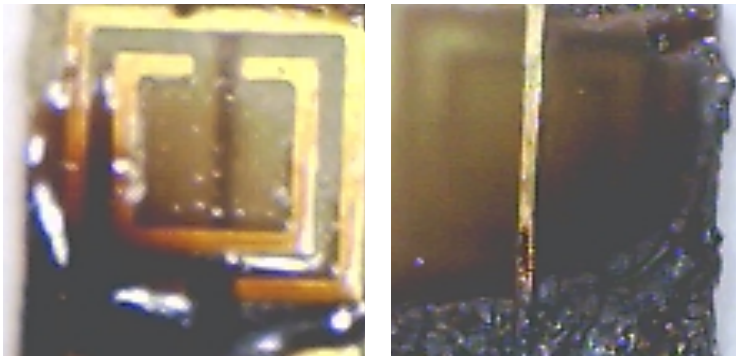


$$\Delta P = \frac{\omega^2 \mu}{\beta_0} \frac{L^3}{2ab} Z^2 \frac{\mathrm{d}}{\mathrm{dX}} \left(\frac{\sin^2(\mathrm{X})}{\mathrm{X}^2} \right) \frac{\mathrm{c}}{\gamma^3} \frac{1}{\mathrm{v}_\mathrm{e}^3} \left(\mathrm{mc}^2 \mathrm{I}_\mathrm{b} / \mathrm{e} \right)$$

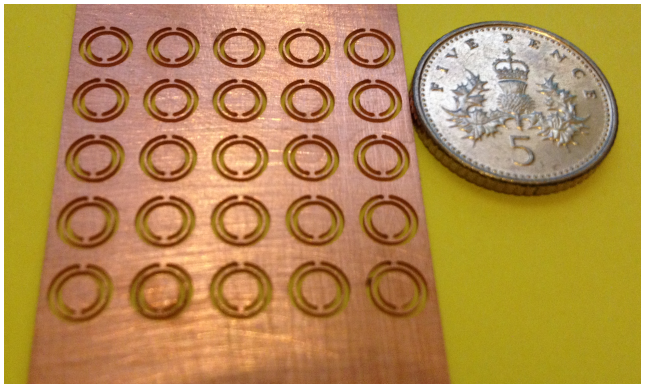
→ **Inverse Cherenkov Accelerator**
→ **Compact Amplifier**

Y. S. Tan and R. Seviour,
Europhysics Letters, 87(3):34005, 2009.

Split Ring Resonant (SSR)



Complementary Split Ring Resonant (CSSR)



Thank You