EE 3130

Introduction to Optoelectronic Engineering,

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EE 3130

Time: M5M6W6 (01:10-03:00 PM, Monday; 02:10-03:00 PM, Wednesday)

Course Description:

- This course is designed for the beginners who are interested in Optoelectronics and Photonics.
- Modern optics, from EM-waves, geometric optics, interference, diffraction, birefringence, liquid crystals, waveguides, displays, lasers, and nonlinear optics, would be involved.
- No background is required.
- **Teaching Method**: in-class lectures with discussion and project studies.

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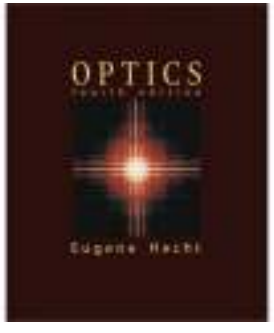
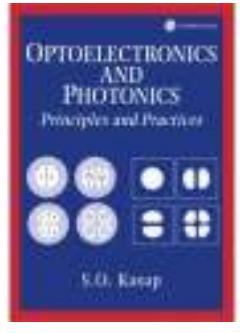
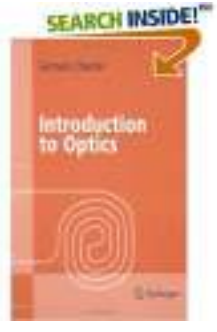
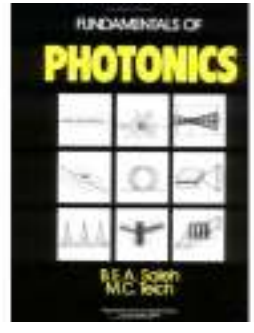
Reference Books

- In-class handouts.
- E. Hecht, "Optics," 4th edition, Addison Wesley (2001).
- S. O. Kasap, "Optoelectronics and Photonics," Prentice Hall (2001).
- G. Chartier, "Introduction to Optics," (2004).
- B. E. A. Saleh and M. C. Teich, "Fundamentals of Photonics," Wiley (1991).
- M. Born and E. Wolf, "Principles of Optics," 7th edition, Cambridge (1999).









Syllabus

1. Introduction to modern photonics,
2. Ray optics (lens, mirrors, prisms, et al.),
3. Wave optics (plane waves and interference),
4. Beam optics (Gaussian beam and resonators),
5. Electromagnetic optics (reflection and refraction),
6. Fourier optics (diffraction and holography),
   Midterm,
7. Crystal optics (birefringence and LCDs),
8. Waveguide optics (waveguides and optical fibers),
9. Photon optics (light quanta and atoms),
10. Laser optics (spontaneous and stimulated emissions),
11. Semiconductor optics (LEDs and LDs),
12. Nonlinear optics,
13. Quantum optics,
    Final exam,
14. Semester oral report,

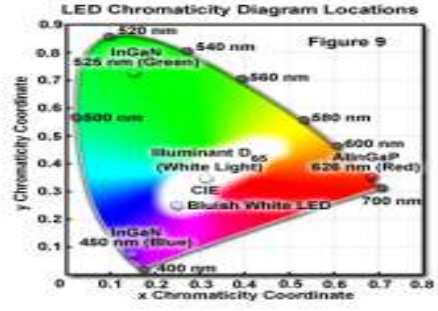
Evaluation

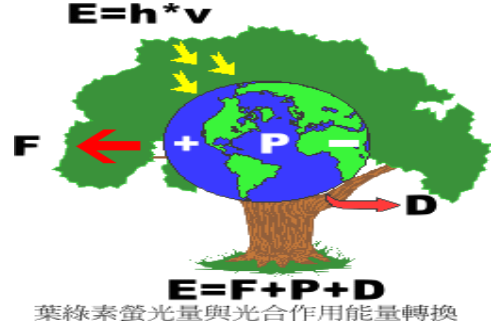
1. Midterm, 40%;
2. Final exam, 40%;
3. Semester oral report, 20%.

- Office hours: 15:30-17:00, Wednesday at Room 523, EECS bldg.
- TA hours:
- For more information: http://mx.nthu.edu.tw/∼rklee

- And God said: Let there be light, and there was light, Genesis, Bible;
- Euclid (300 B.C.): geometrical (ray) optics;
- Descartes (1596-1650): a pressure transmitted through the *aether*;
- Newton (1642-1727): the quality of color;
- Huygens (1629-1695): the wave theory of light;
- Maxwell (1831-1879): the electromagnetic waves;
- Planck (1858-1947): the quantum theory;
- Einstein (1879-1955): light quanta, or photon;

- Optics,
- Light,
- Ray,
- Wave,
- Color,
- Image,
- Electromagnetic Wave,
- Photon,
- massless Boson $\leftrightarrow$ Fermion





葉綠素螢光量與光合作用能量轉換

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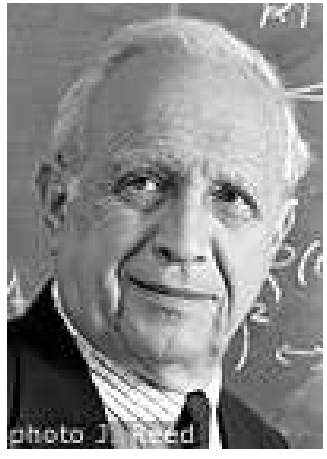
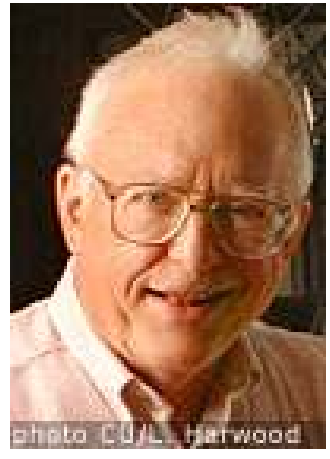
2005 Nobel Laureates

Glauber(Harvard) Hall(JILA) Hänsch(MPI)


Roy J. Glauber: "for his contribution to the quantum theory of optical coherence,"

John L. Hall and Theodor W. Hänsch: "for their contributions to the development of laser-based precision spectroscopy, including the optical frequency comb technique."

from: http://nobelprize.org/

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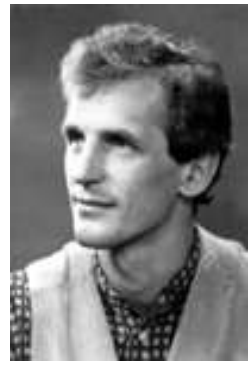
Nobel Laureats on Photonics: I

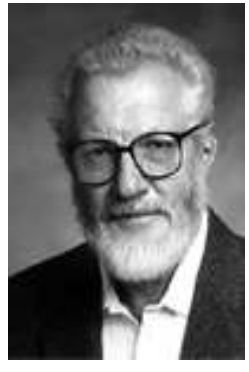






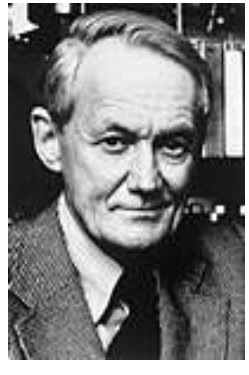

Quant-Opt.(2005) Comb(2005) Comb(2005) BEC(2001) BEC(2001) BEC(2001)






heterostructure(2000) heter.(2000) IC(2000) lasercooling(1997) L.C.(1997) L.C.(1997)






spectroscopy(1981) spect.(1981) spect.(1981) holography(1971) laser(1964) laser(1964)

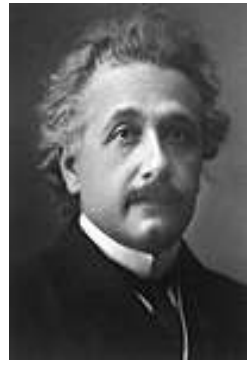
Nobel Laureats on Photonics: II



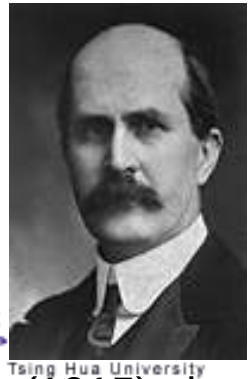



laser(1964) transistor(1956) trans.(1956) trans.(1956) Rabi(1944) Raman(1930)



de Broglie(1929) X-ray spect.(1924) photoelectric(1923) P.O.(1921) quanta(1918) Bragg(1915)

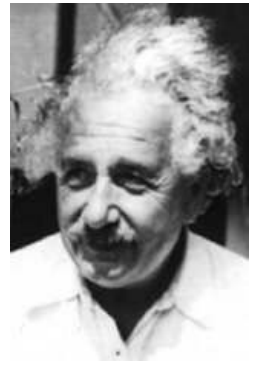


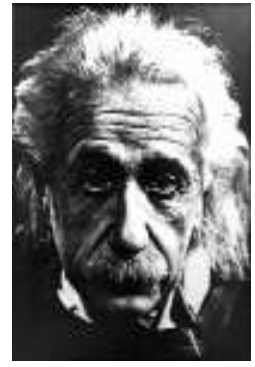
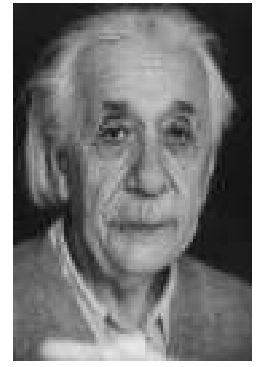



Bragg(1915) photography(1908) Michelson(1907) cathode(1905) Rayleigh(1904) X-ray(1901)

Einstein on Photons





- Particle behavior of light: Photoelectric effect,
- Photon-atom interaction: A/B coefficients,
- Statistics of photons: Bose-Einstein statistics,
- Speed of photons: Special Relativity,
- Mass of photons: General Relativity,
- Incompleteness of Quantum Mechanics: EPR entanglement.

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“100年前愛因斯坦對光電效應的闡釋及理論，揭開了近代量子物理的新頁，奠訂了現代量子光學的基礎，導引了20世紀光電科技璀璨的研發，進而帶動光電產業的澎磚發展，徹底的改變了人類的生活…”

- 劉容生 - 科學人4月份“讓物理光耀世界”

World Year of PHYSICS 2005
www.physics2005.org

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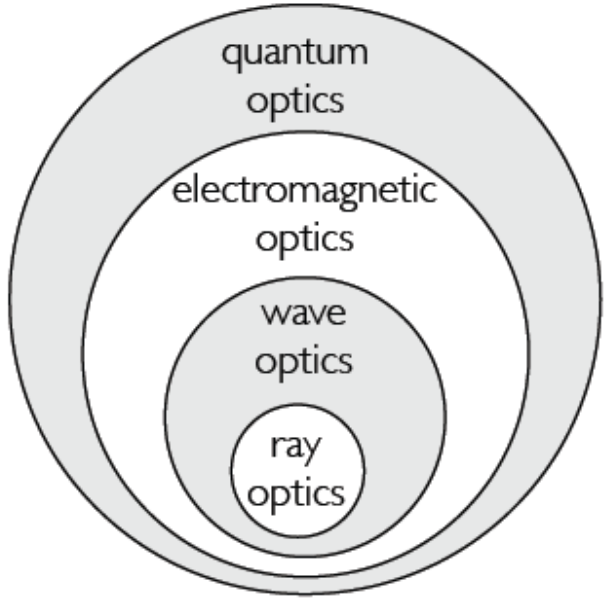
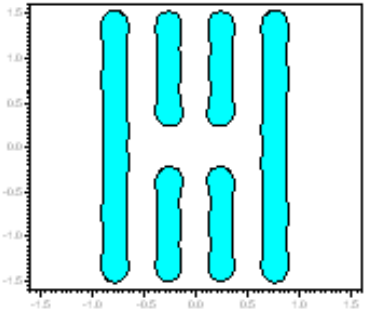
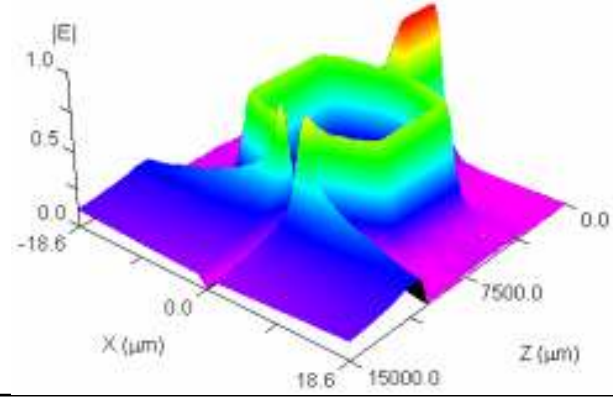
Prof. YS Liu,

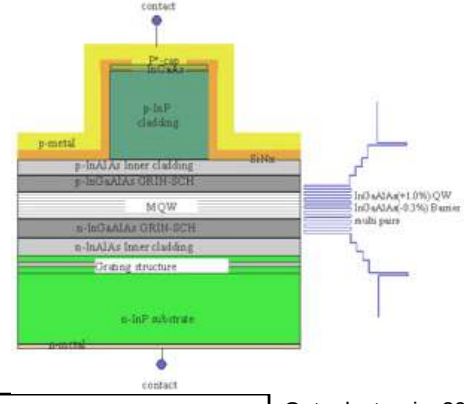
Photonics

Modifying and *Manipulating* the properties of light, its classical and quantum properties



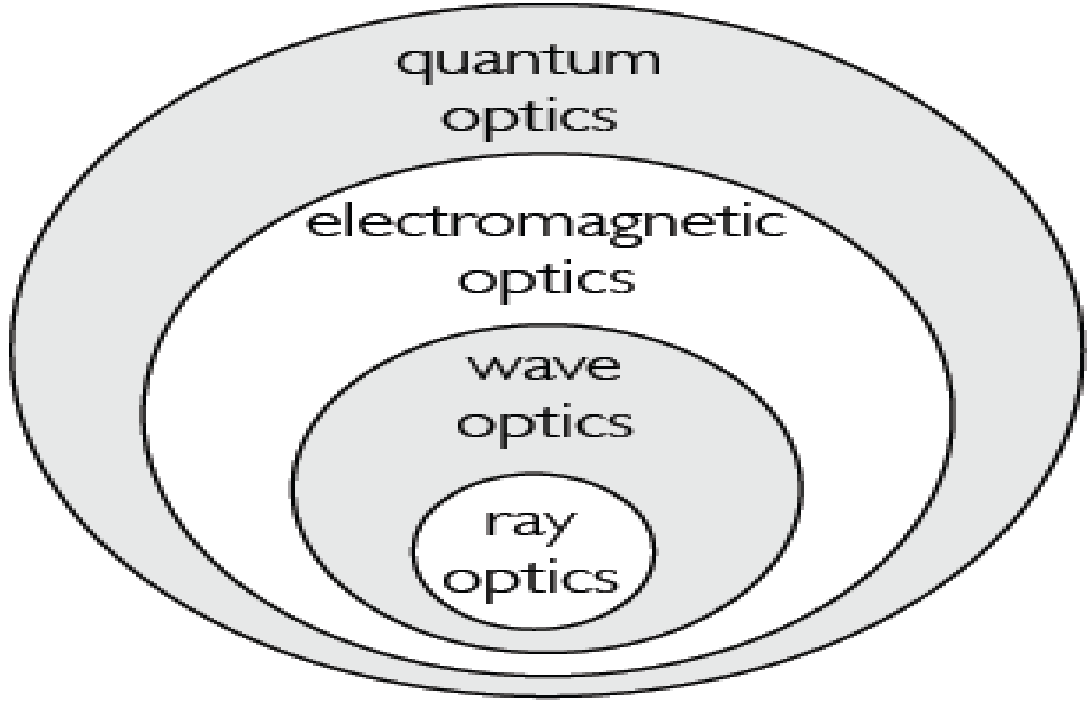






Contents of the Lecutres

1. Ray Optics (lens, mirrors, prisms, et al.); Hecht Ch5.
2. Wave Optics (plane waves and interference); Hecht Ch. 2.
3. Electromagnetic Optics, Photons, and Lights; Hecht Ch. 3.
4. The propagation of Light (reflection and refraction); Hecht Ch. 4.
5. Beam Optics (Gaussian beam and resonators);
6. Fourier Optics (diffraction and holography);



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- Nonlinear optics,
- Quantum optics,
- Semester oral report.

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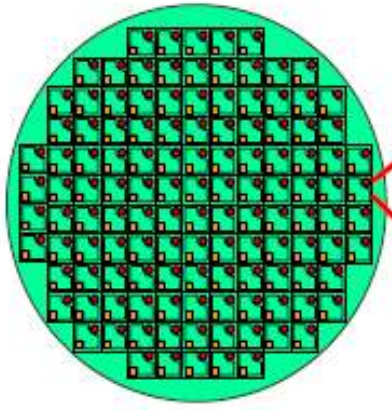
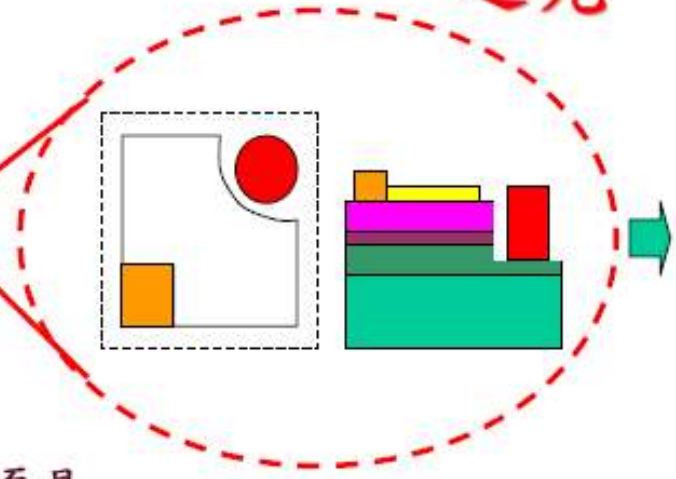
LCD and Dispaly

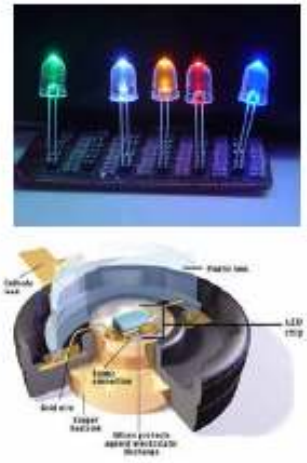
發光二極體(LED) – 今日之星、明日之光



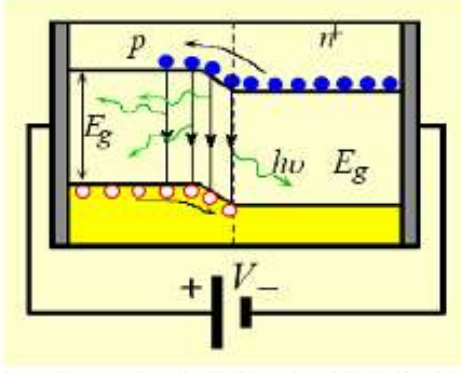
以半導體製程技術在磊晶片上製作許多的LED晶粒



LED晶粒結構示意圖



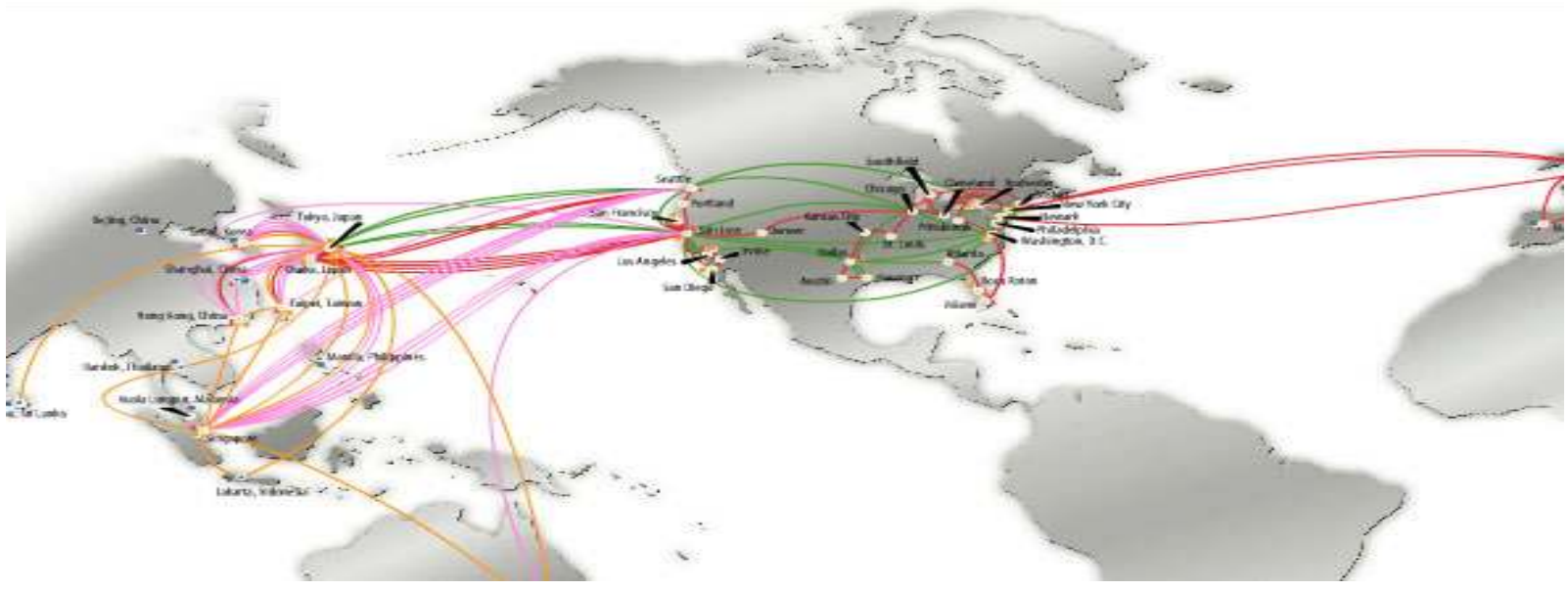
不同封裝型式之LED

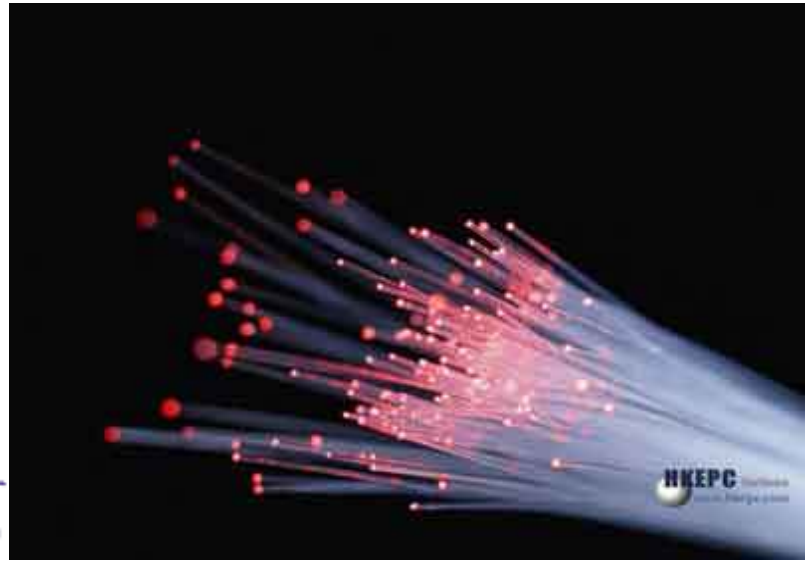


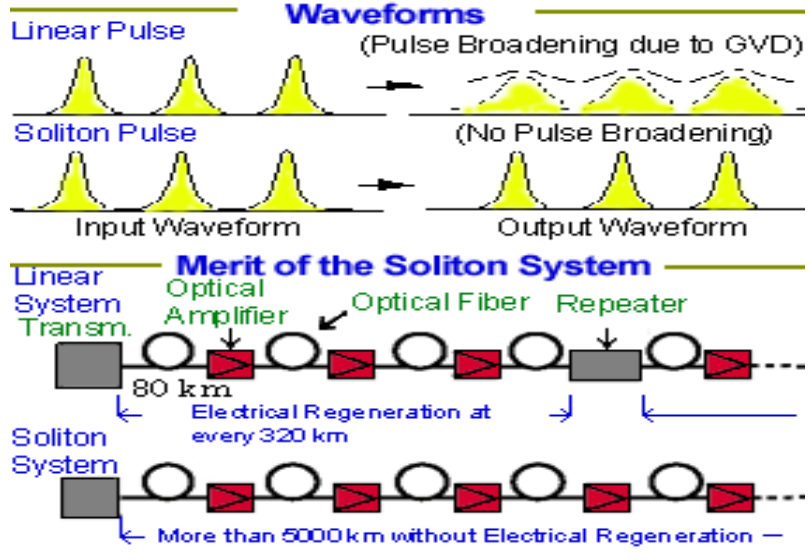
發光二極體基本發光原理

發光二極體相關應用

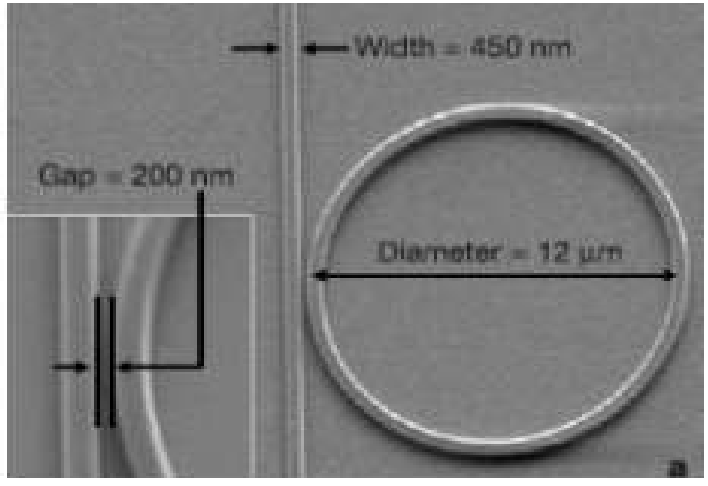
Optical Fibers and Communications

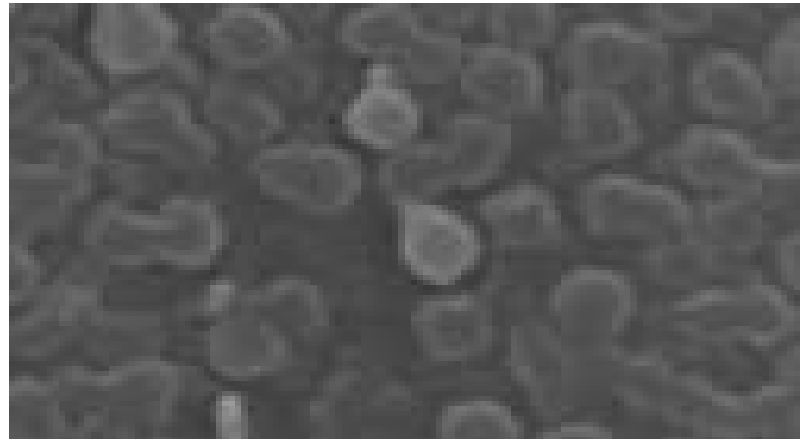


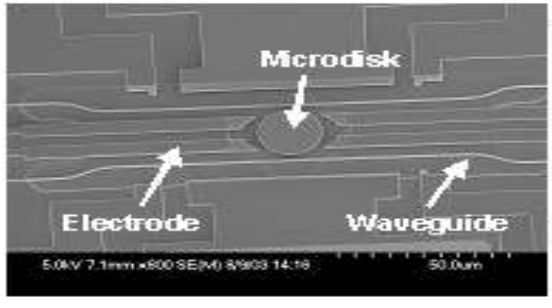


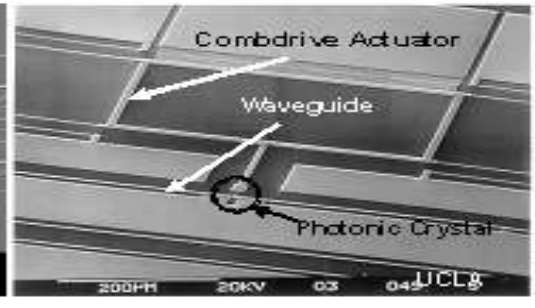


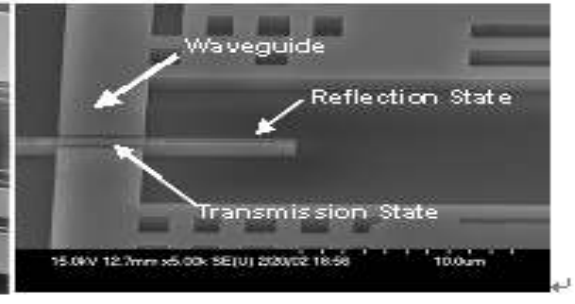
Waveguides and Integrated Optics

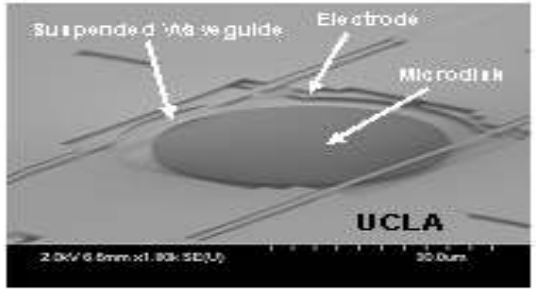


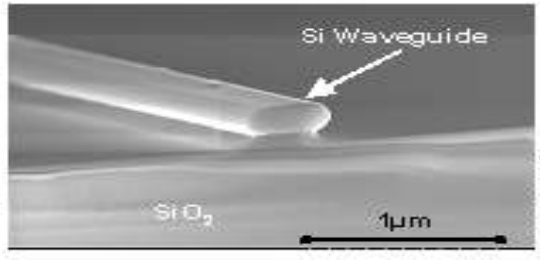


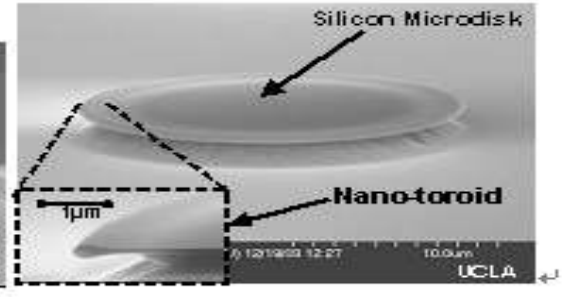












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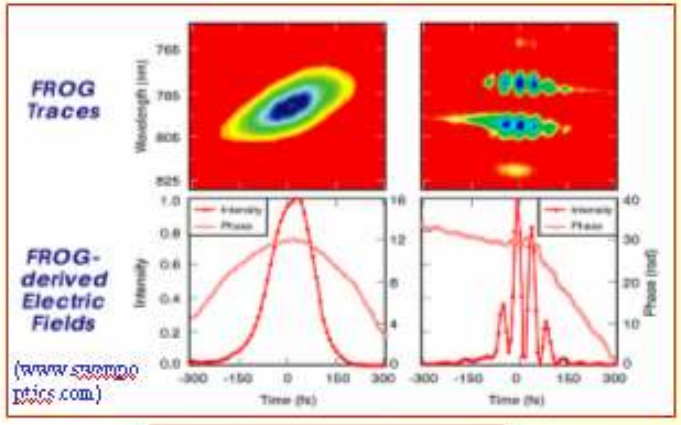
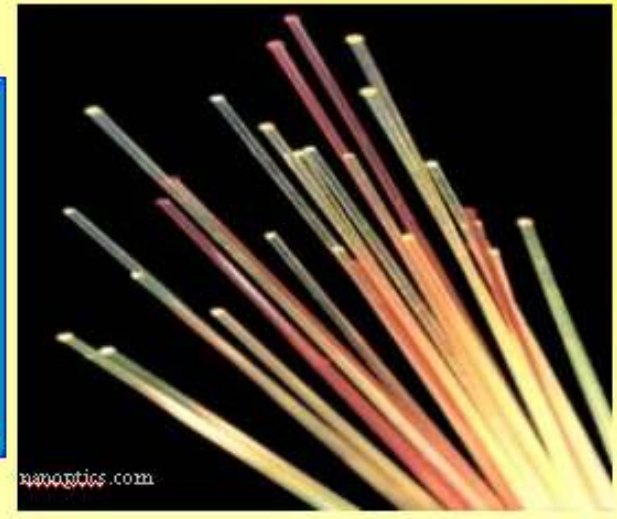
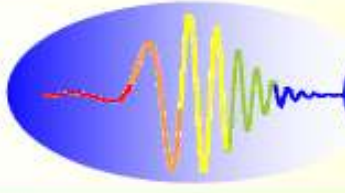
Lasers and Bio-photonics



飛秒脈衝量測

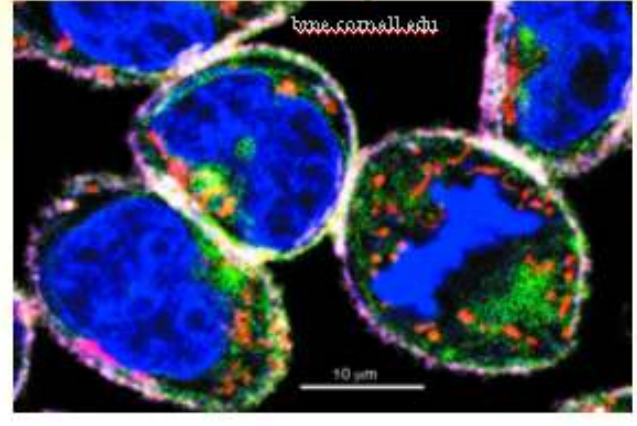
高速光通纖訊



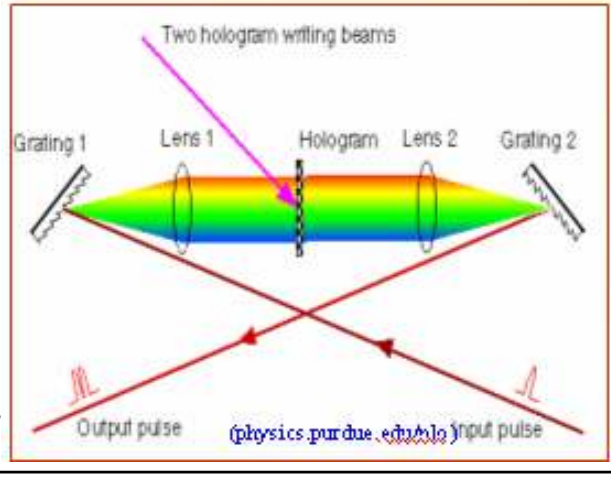


超短雷射光脈衝

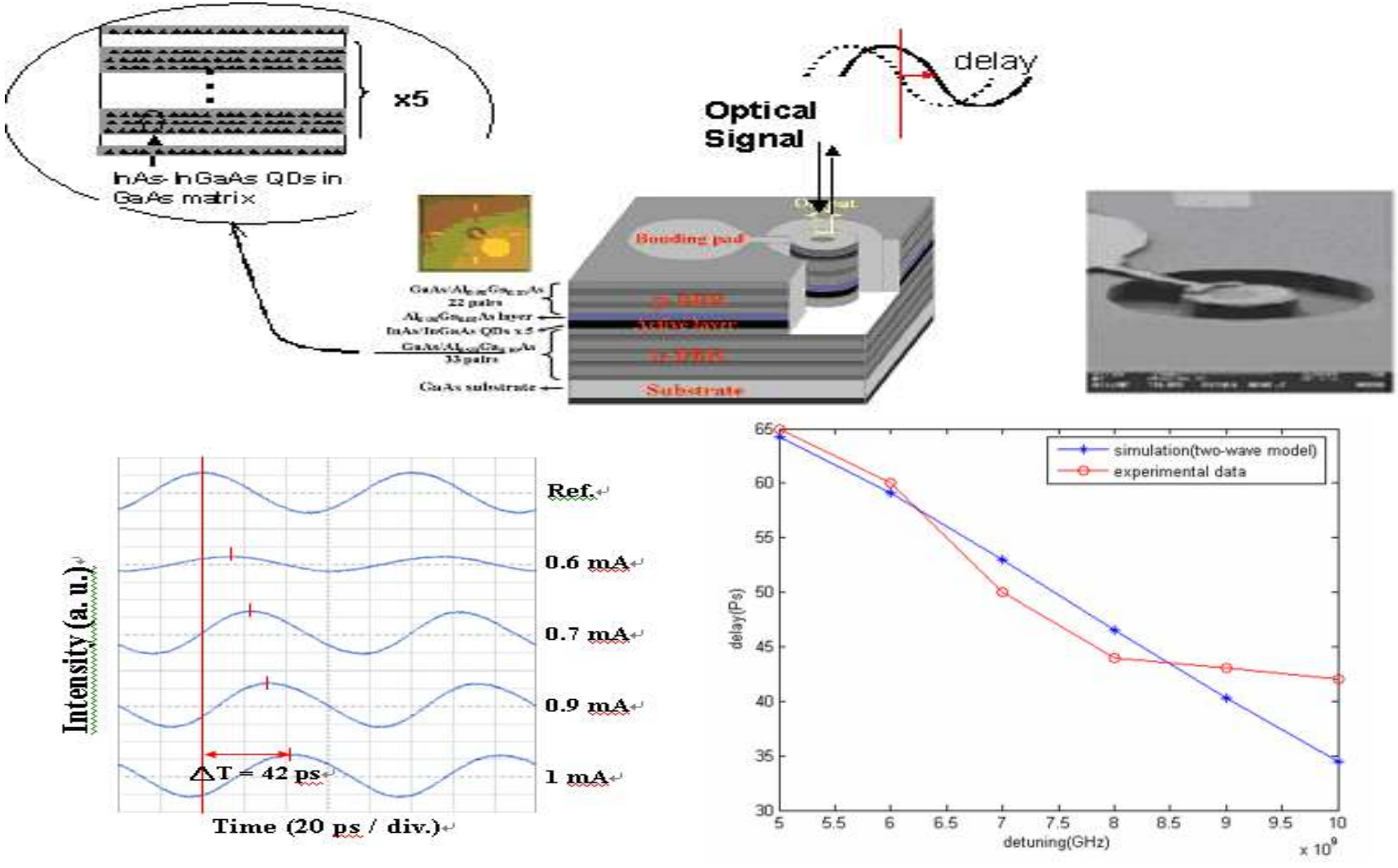
非線性生醫影像



超快光訊號處理



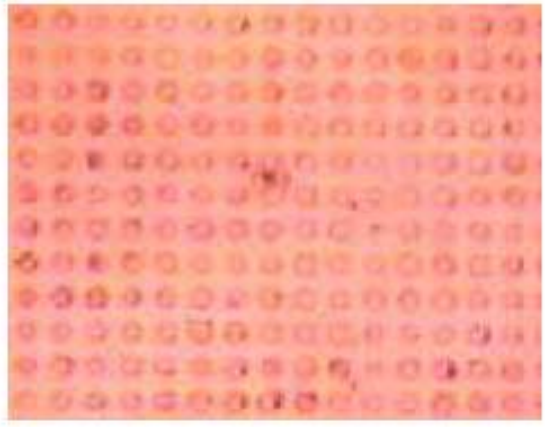
Slow-light in QD VCSELs

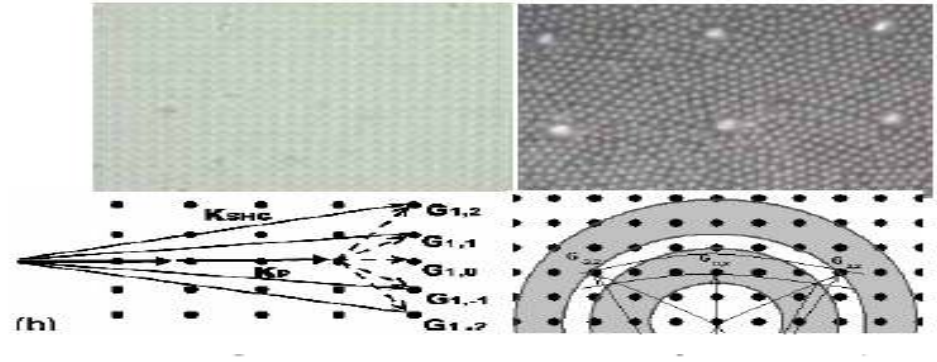


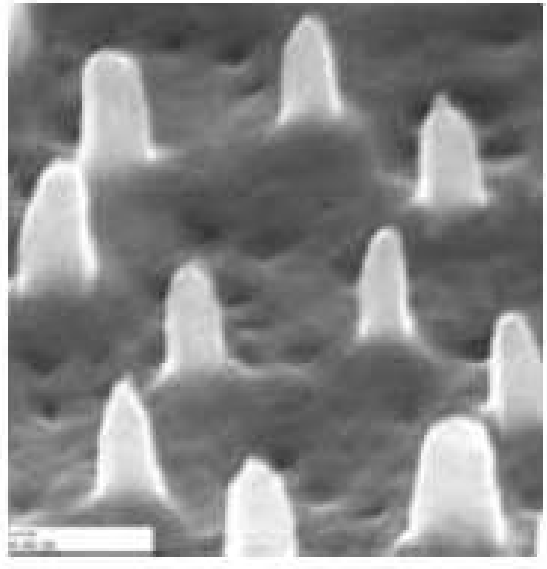
Courtesy: ITRI

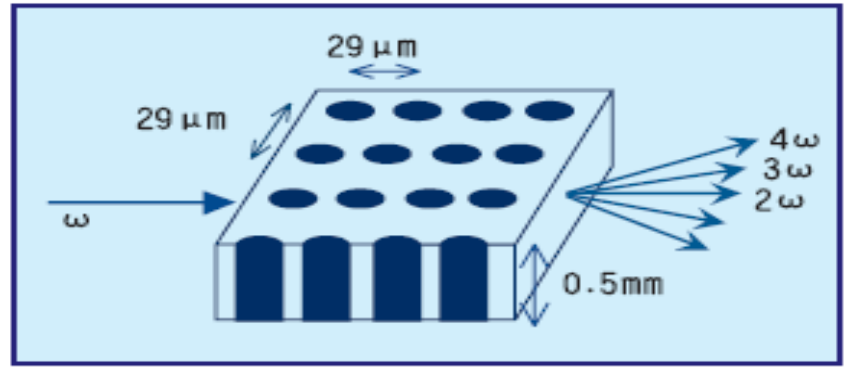
Simulations (primary results): Chia-Sheng Chou and Ray-Kuang Lee

Wavelength tunability of SHG from 2D χ^2 nonlinear PhCs with a tetragonal lattice









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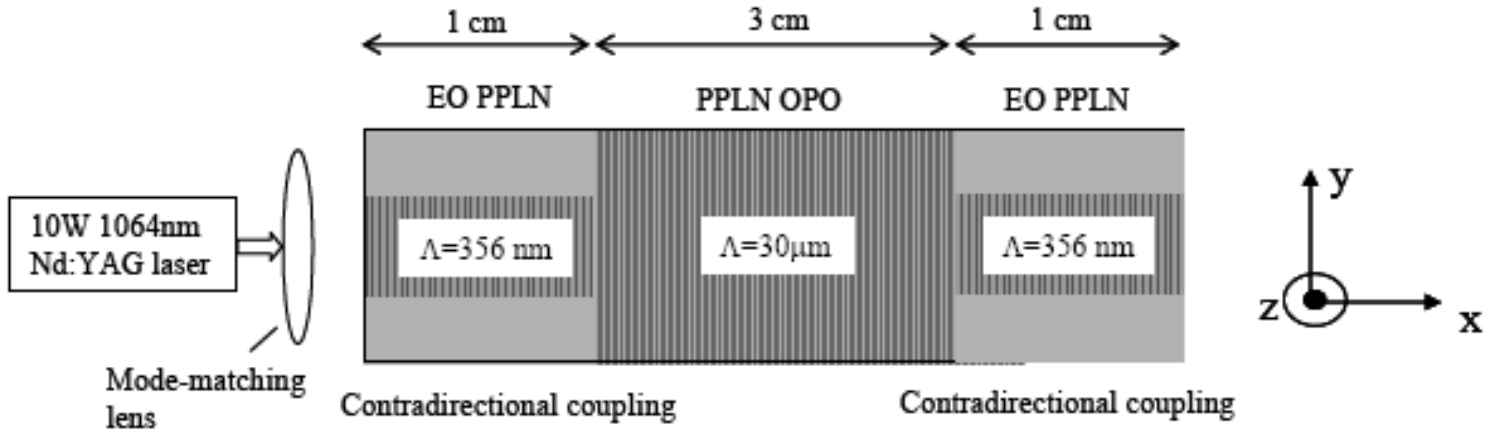
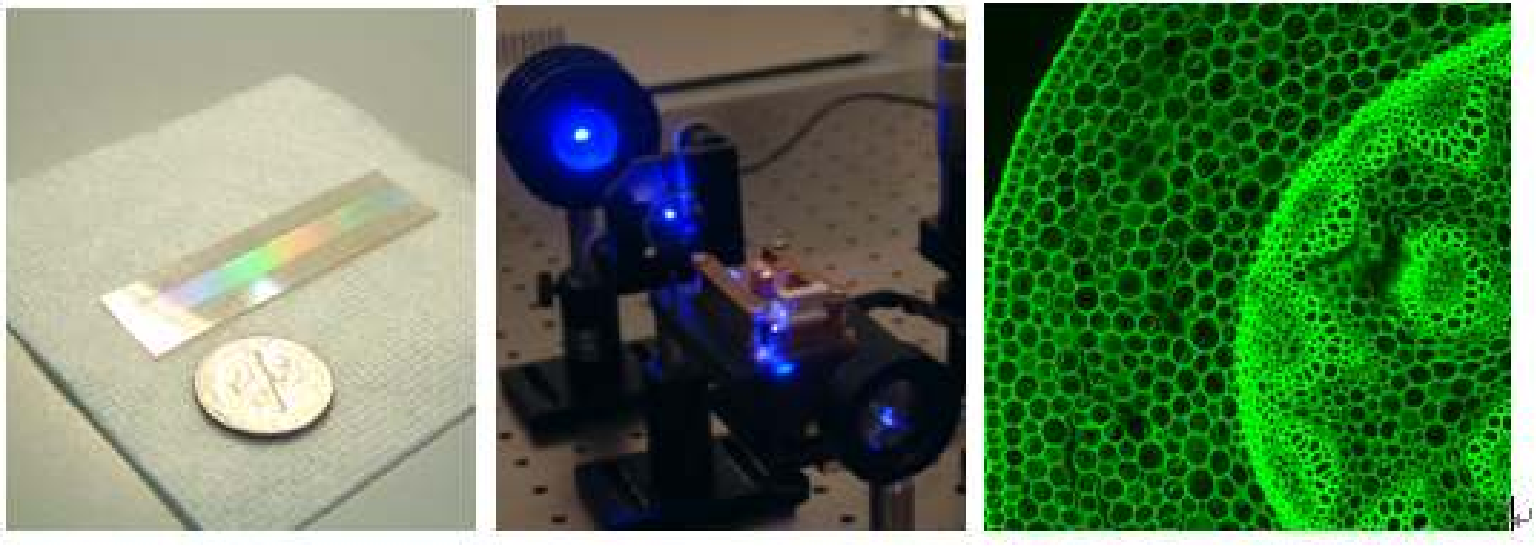
Courtesy: L.H. Peng (NTU, $LiNbO_3$, $LiTaO_3$ and GaN)

L.-H. Peng, C.-C. Hsu, J. Ng, and A. H. Kung, *Appl. Phys. Lett.* **84**, 3250 (2004).

Monolithic QPM nonlinear crystal for laser and bio-image

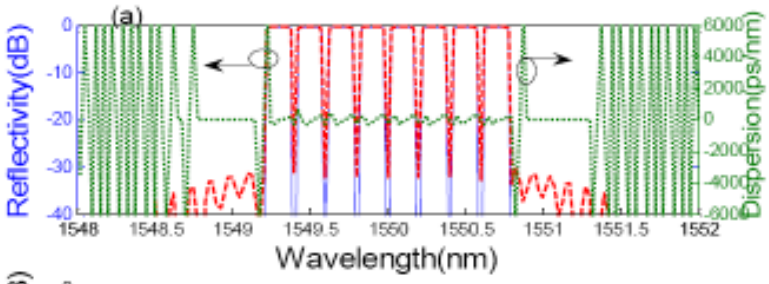


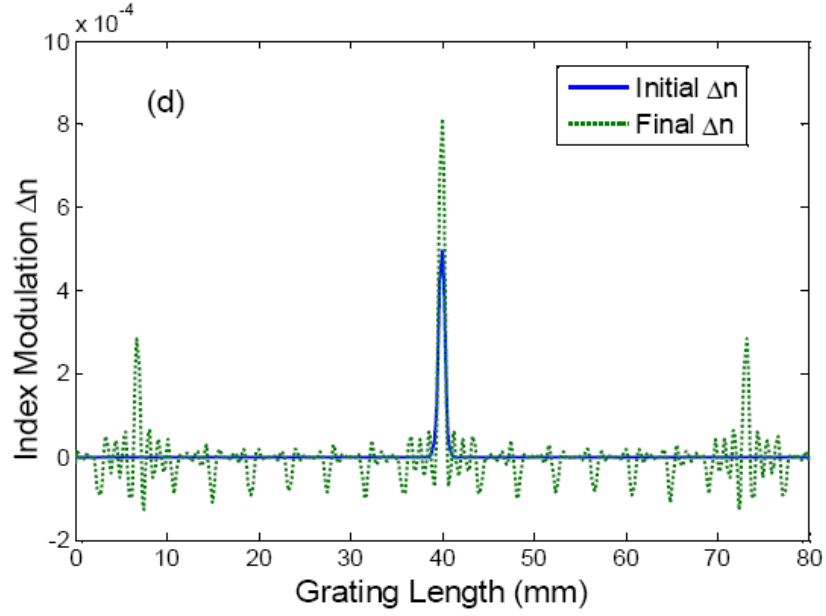


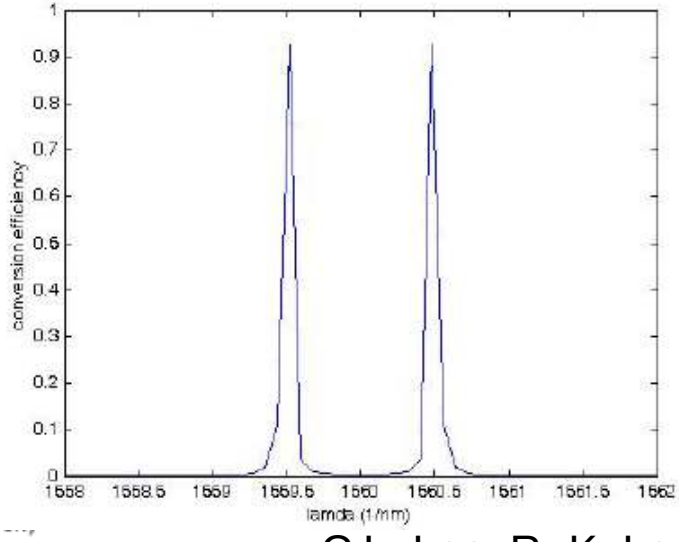
Courtesy: Y.C. Huang (NTHU)

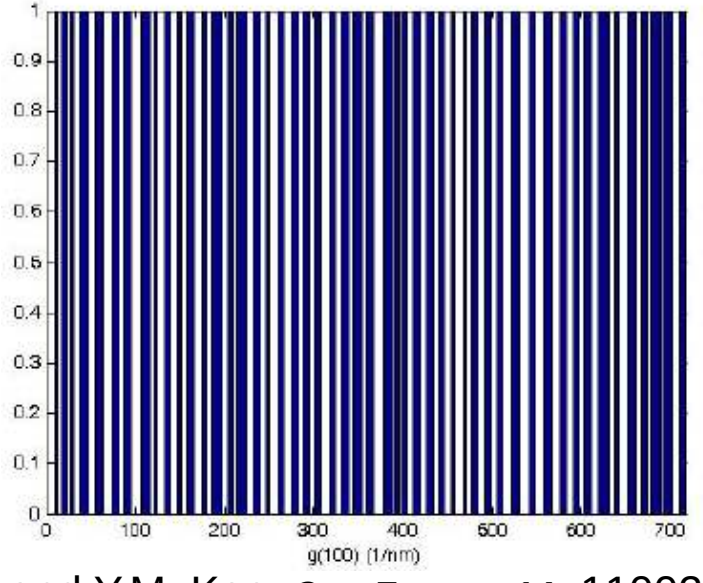
Y. C. Huang *et al.*, *Opt. Lett.* **30**, 1405 (2005); *Opt. Lett.* **31**, 3483 (2006).

Synthesis of Fiber Bragg gratings and QPM devices





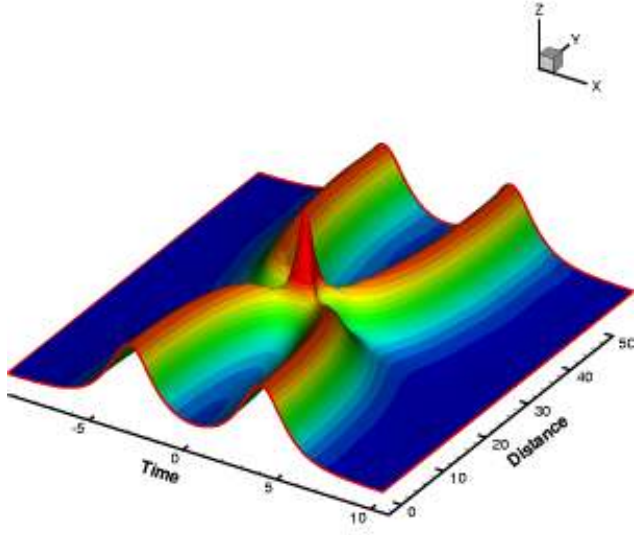


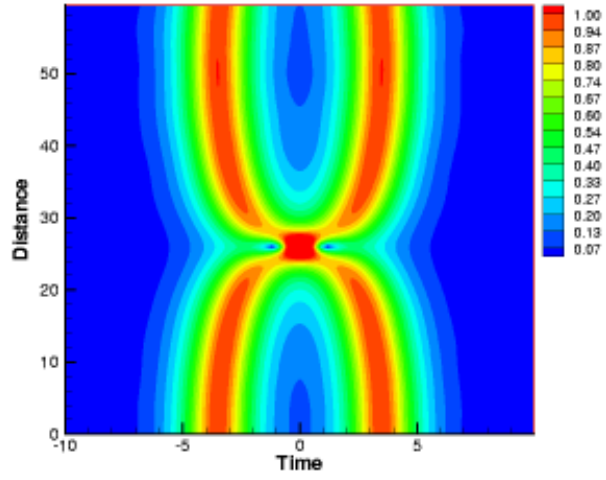


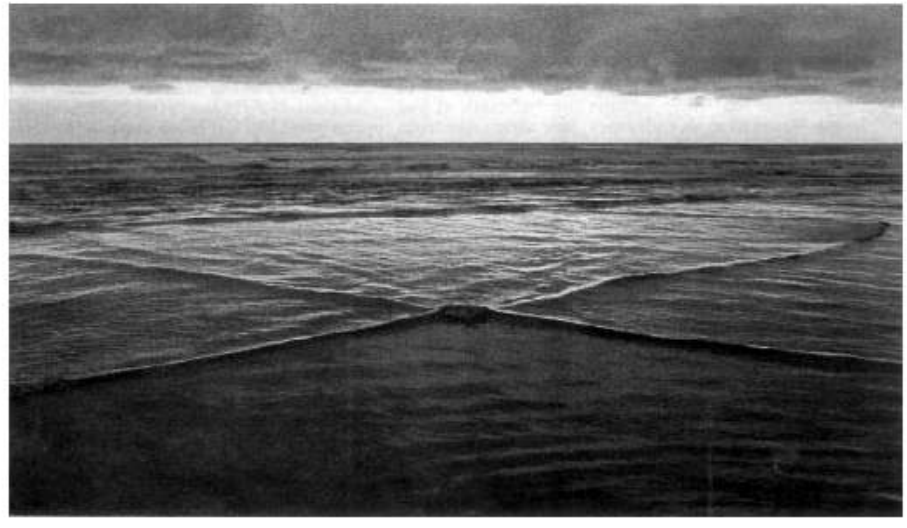
C.L. Lee, R.-K. Lee, and Y.M. Kao, *Opt. Express* **14**, 11002 (2006).

Wave-particle characteristics of solitons

Collision between solitons







Courtesy of T. Toedterneier

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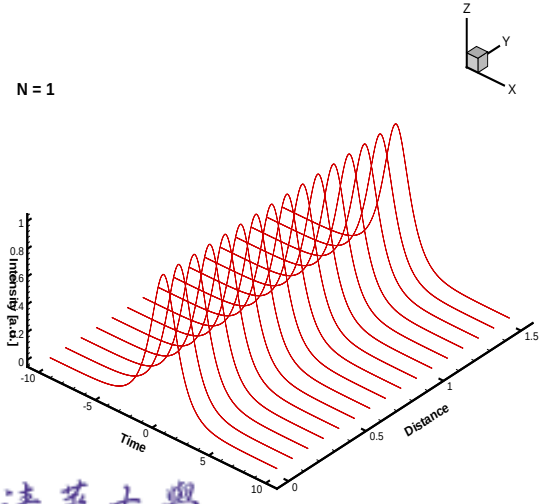
Solitons in optical fibers

Nonlinear Schrödinger Equation:

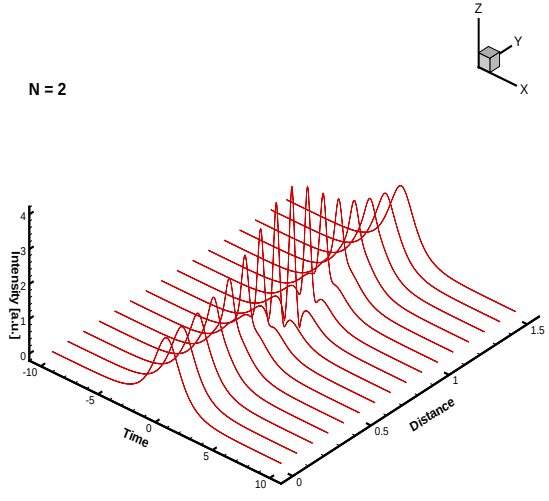
$$iU_z(z,t) = -\frac{D}{2}U_{tt}(z,t) - |U(z,t)|^2 U(z,t)$$

Fundamental soliton:

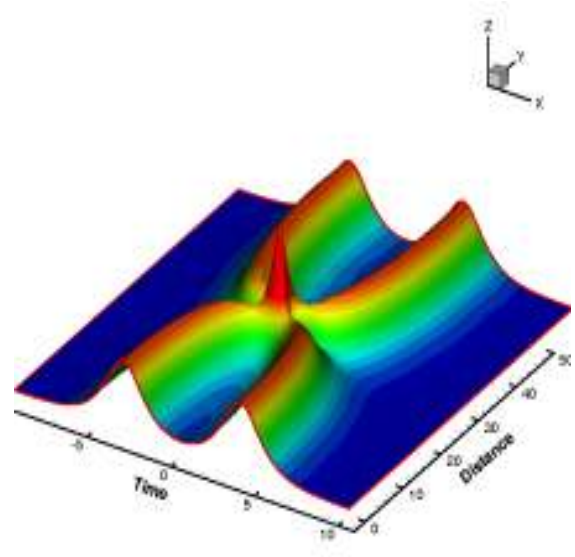
$$U(z,t) = \frac{n_0}{2} exp[i\frac{n_0^2}{8}z + i\theta_0] sech[\frac{n_0}{2}t]$$



Fundamental

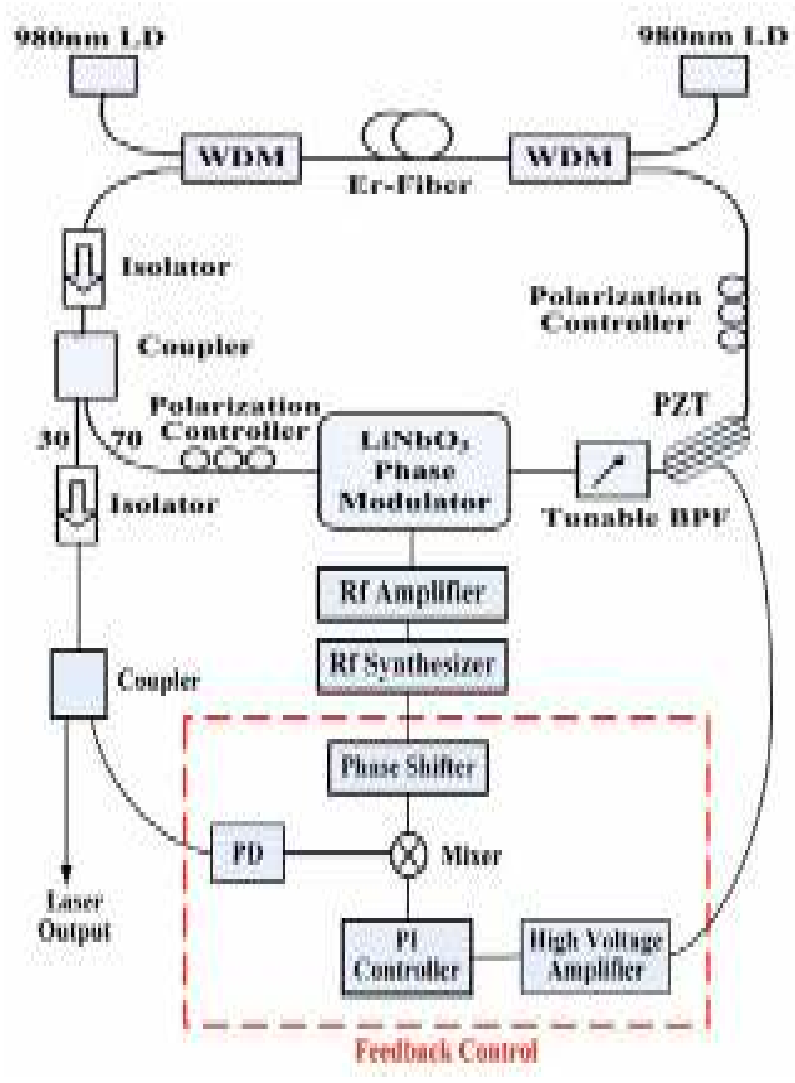


Higher-order ($N = 2$)



Soliton interaction

Stable new bound soliton pairs in a 10GHz hybrid ML fiber laser



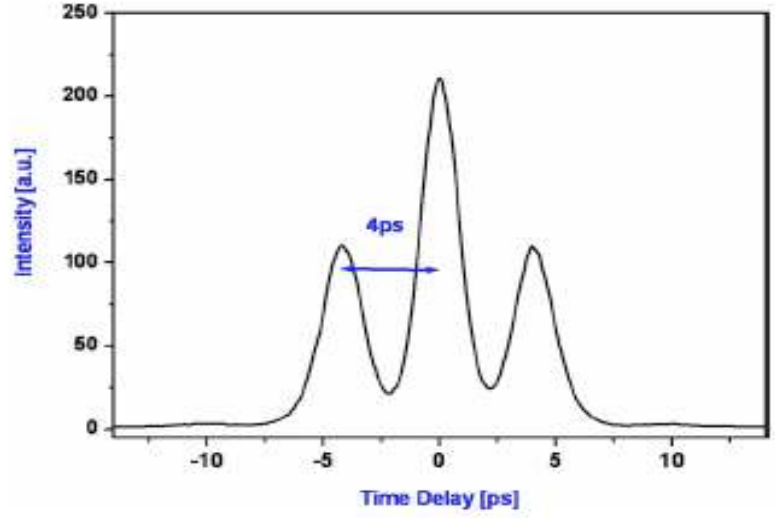
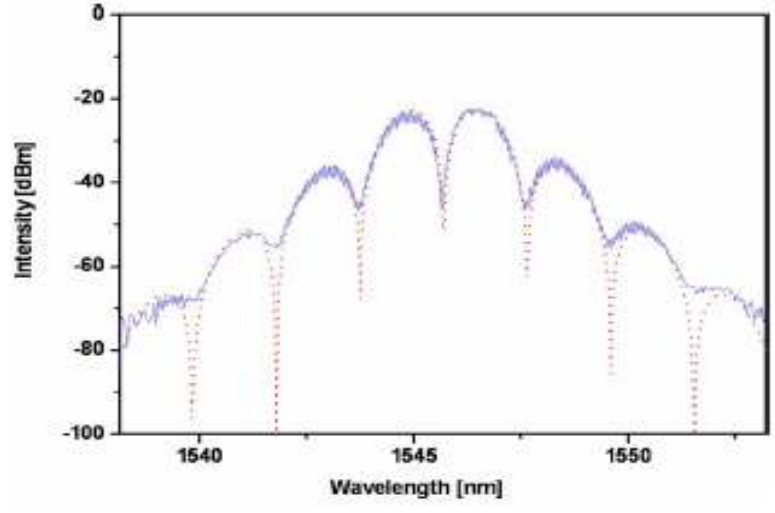


Fig. 2. (Color online) SHG autocorrelation trace of the bound soliton pair.



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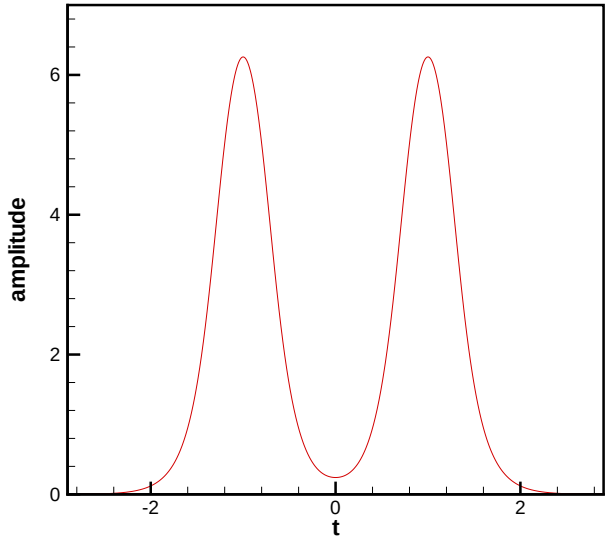
Courtesy: Y. Lai (NCTU)

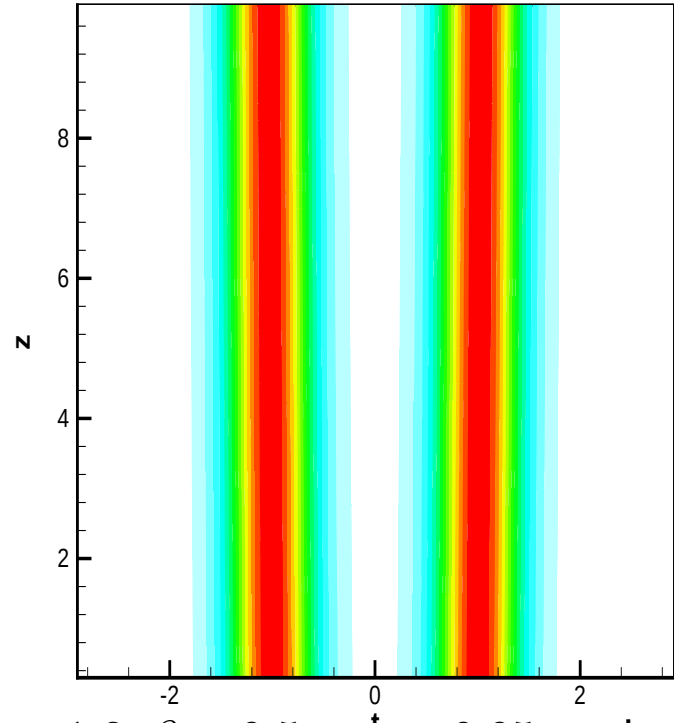
W.-W. Hsiang, C.-Y. Lin, and Y. Lai, *Opt. Lett.* **31**, 1627 (2006).

Degenerate bound-state soliton pair solutions in Complex Ginzburg-Landau equation

There exist three bound pair solutions with the same separation and amplitude but different relative phases, i.e. $\theta = 0$ (in-phase), $\pi/2$, and $\theta = \pi$ (out-of-phase).

$$U(z,t) = U_0(z, t+\rho) + U_0(z, t-\rho)e^{i\theta},$$



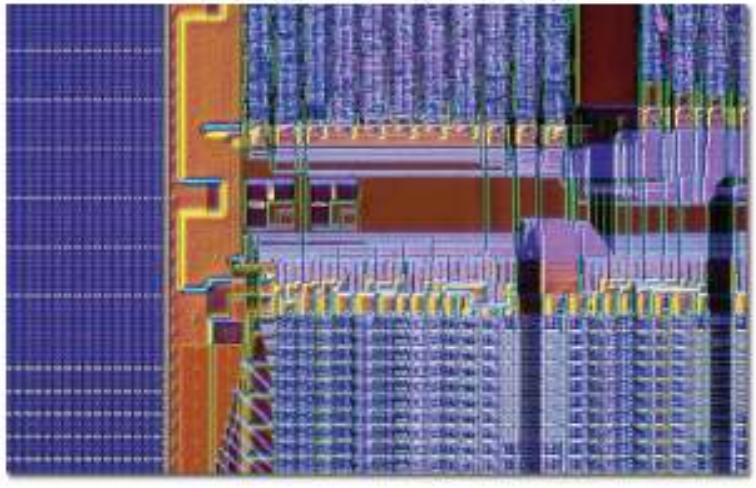


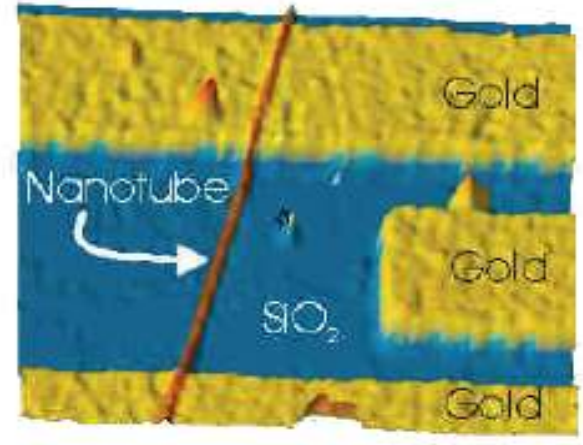
Simulation parameters: $D = 1$, $\delta = -0.01$, $\epsilon = 1.8$, $\beta = 0.5$, $\mu = -0.05$, and $\nu = 0$.

N. N. Akhmediev, A. Ankiewicz, and J. M. Soto-Crespo, *Phys. Rev. Lett.* **79**, 4047 (1997).

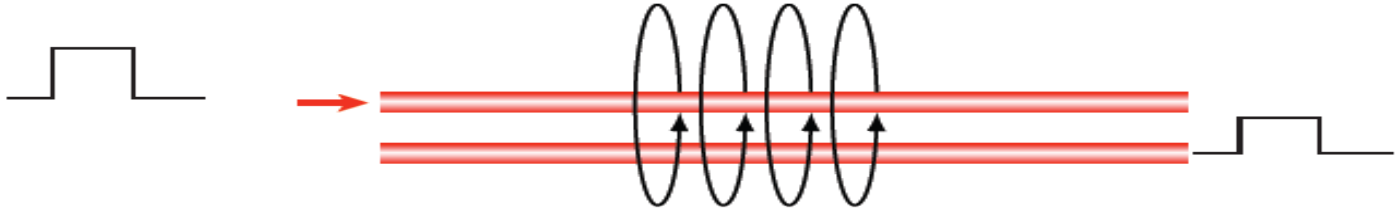
Bottle for Electric Circuits

AMD Athlon CPU in a light microscope

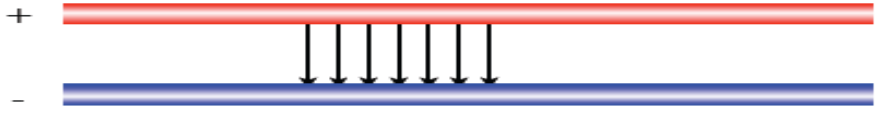




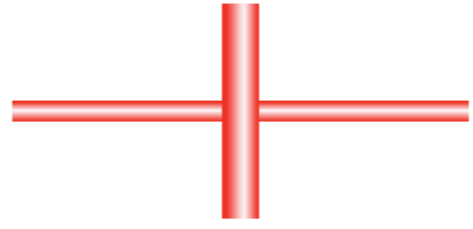
charges influence each other (thats why our electronics works!)



capacity



short circuit



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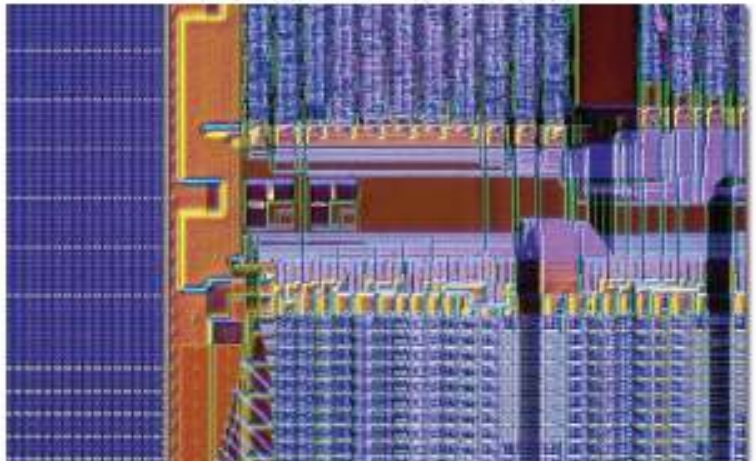
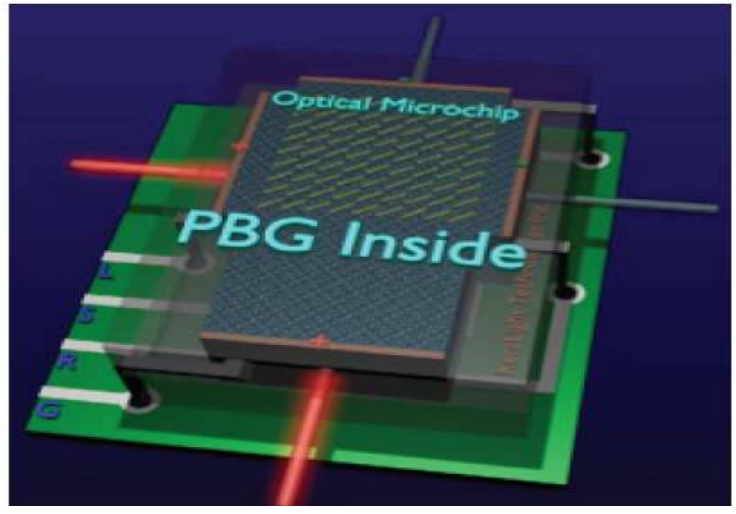
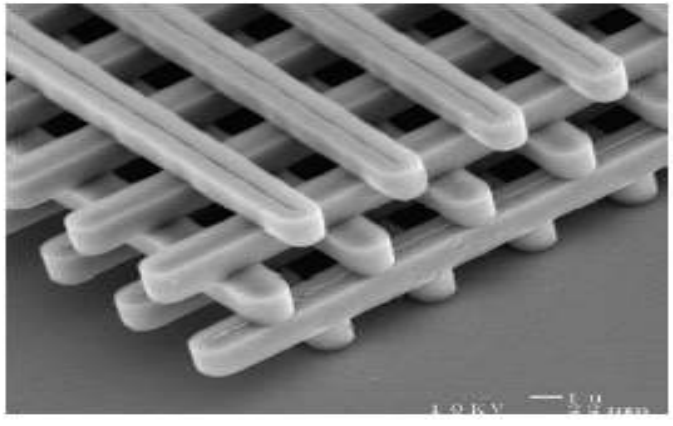
Photonic Crystals

Simulation of 2-dimensional photonic crystal waveguide

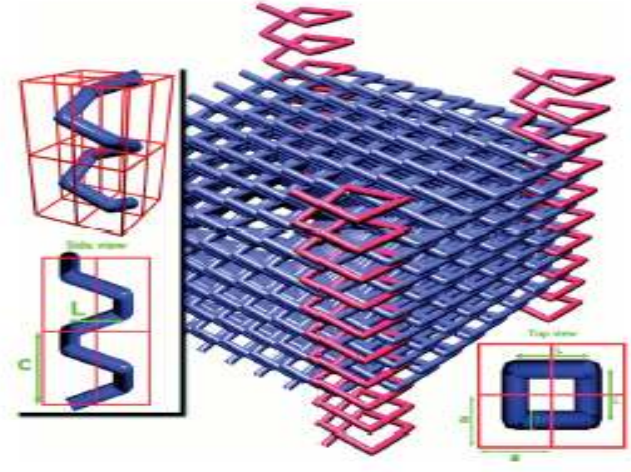
AMD Athlon CPU in a light microscope





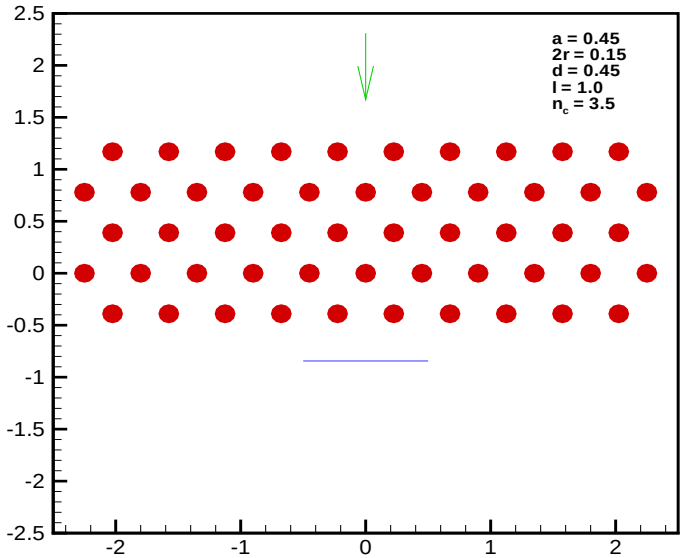


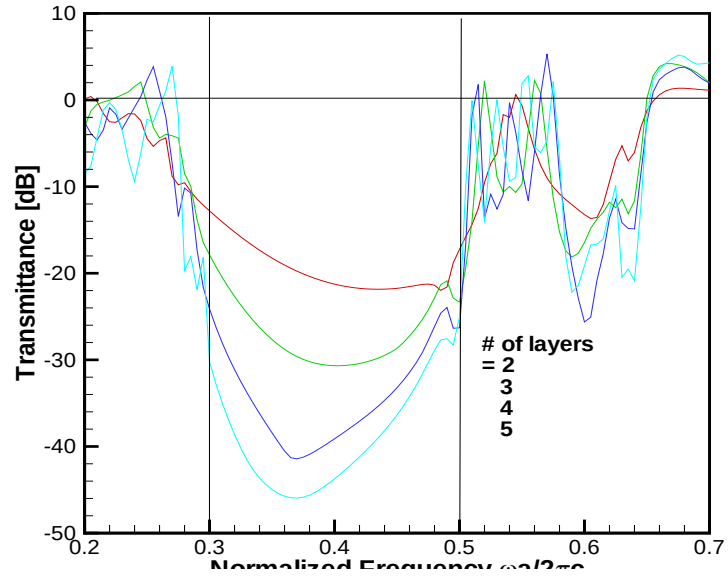
S.Y. Lin et al., Nature 394, 251 (1998)

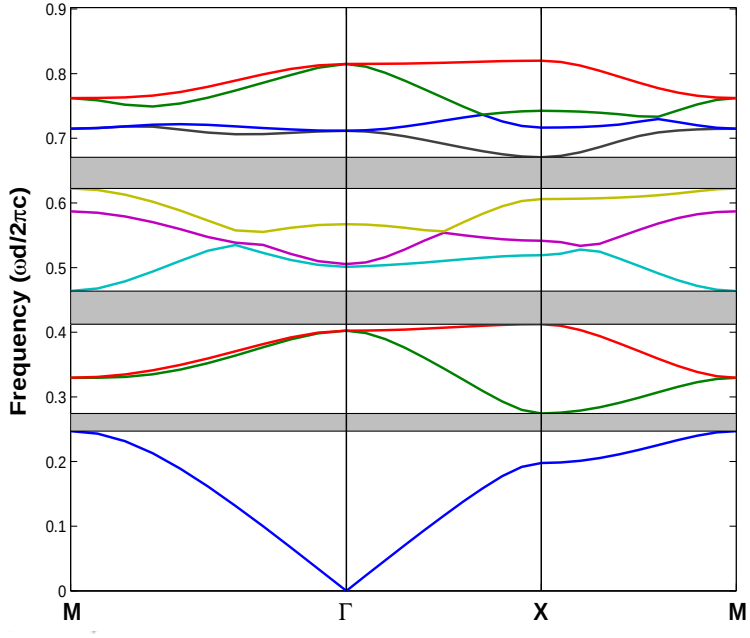


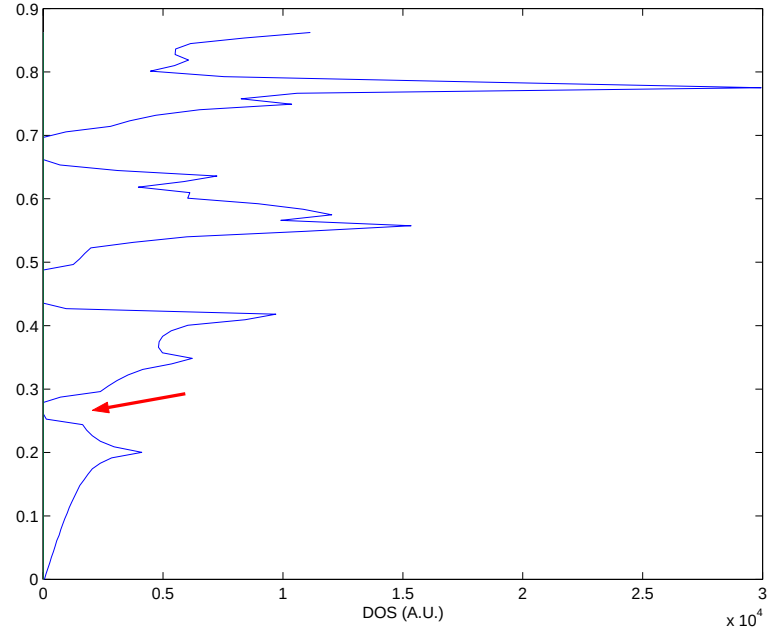
O. Toader and S. John, Science 292, 1133 (2001)

Photonic Bandgap Crystals: two(high)-dimension









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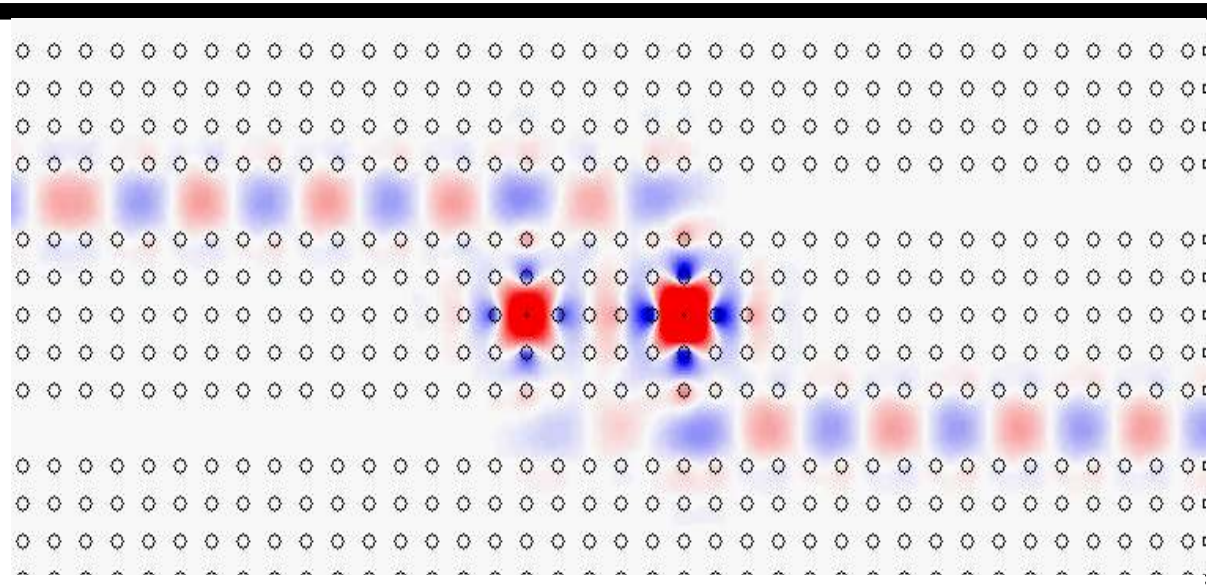
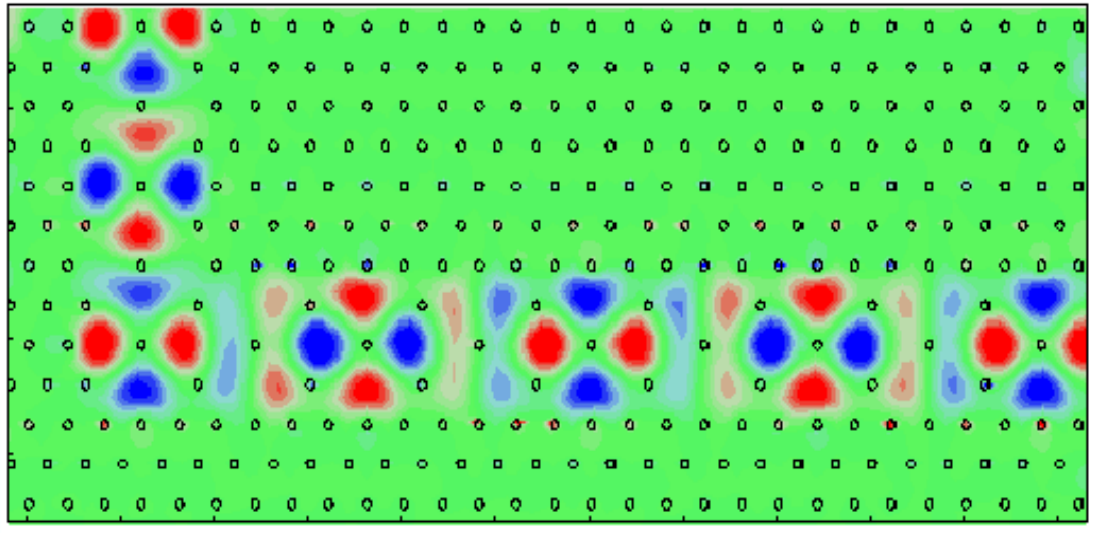
Photonic Crystals Waveguides





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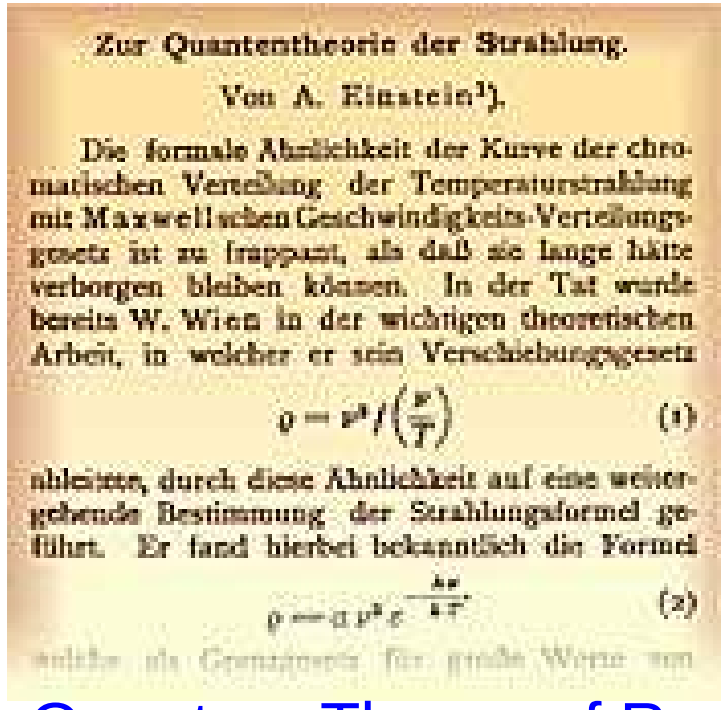
Start animation

Courtesy: Bin-Shei Lin

Einstein on Radiation



Zur Quantentheorie der Strahlung.

Von A. Einstein[1]).

Die formale Ähnlichkeit der Kurve der chromatischen Verteilung der Temperaturstrahlung mit Maxwellschen Geschwindigkeits-Verteilungsgesetz ist zu frappant, als daß sie lange hätte verborgen bleiben können. In der Tat wurde bereits W. Wien in der wichtigen theoretischen Arbeit, in welcher er sein Verschiebungsgesetz

$$\varrho = \nu^3 f\left(\frac{\nu}{T}\right) \qquad (1)$$

ableitete, durch diese Ähnlichkeit auf eine weitergehende Bestimmung der Strahlungsformel geführt. Er fand hierbei bekanntlich die Formel

$$\varrho = \alpha \nu^3 e^{-\frac{h\nu}{kT}} \qquad (2)$$

"On the Quantum Theory of Radiation"

$$\rho(\nu_0) = \frac{A/B}{e^{h\nu_0/kT} - 1}$$

$$\frac{A}{B} = \frac{8\pi h\nu_0^3}{c^3}$$

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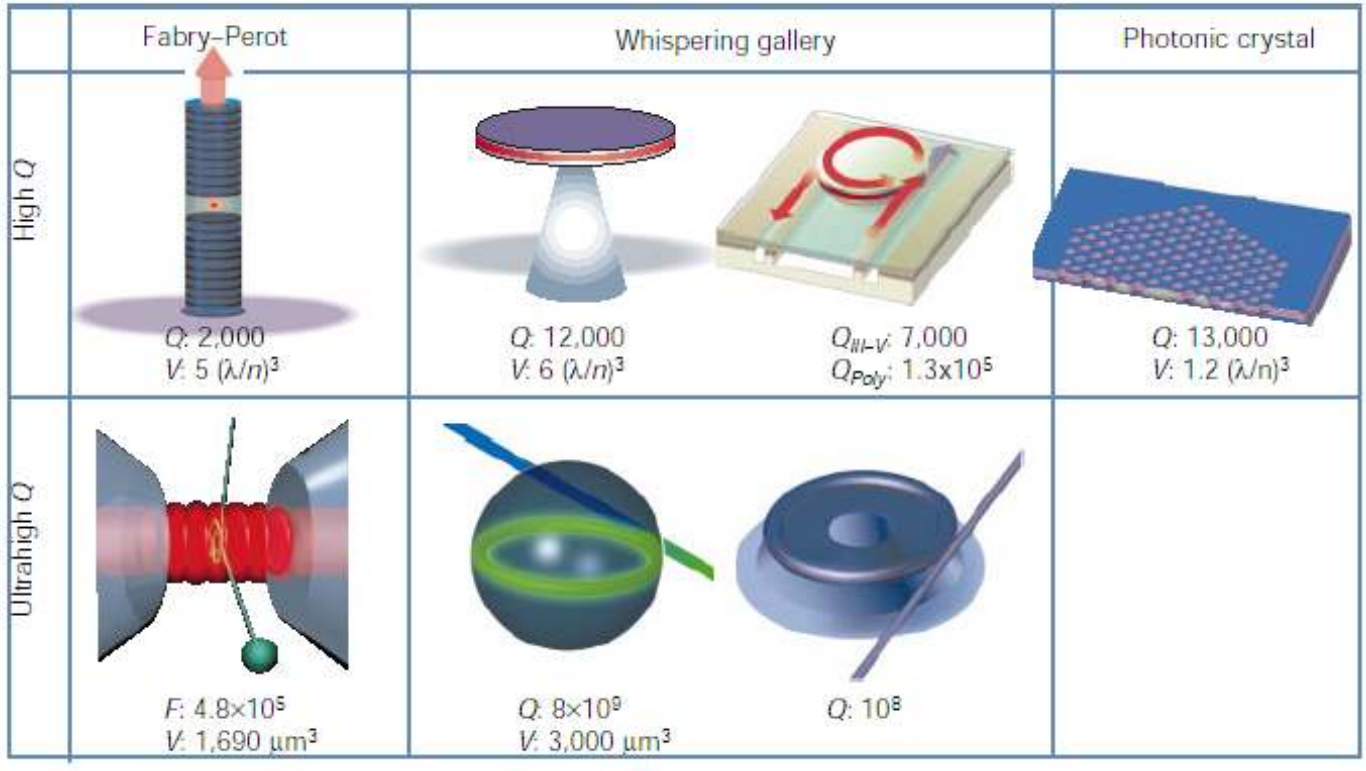
A. Einstein, *Phys. Z.* **18**, 121 (1917).

D. Kleppner, "Rereading Einstein on Radiation," *Physics Today* **58**, 30 (Feb. 2005).

Purcell effect: Cavity-QED (Quantum ElectroDynamics)



E. M. Purcell, *Phys. Rev.* **69** (1946).

Nobel laureate Edward Mills Purcell (shared the prize with Felix Bloch) in 1952,

for their contribution to nuclear magnetic precision measurements.

from: K. J. Vahala, *Nature* **424**, 839 (2003).

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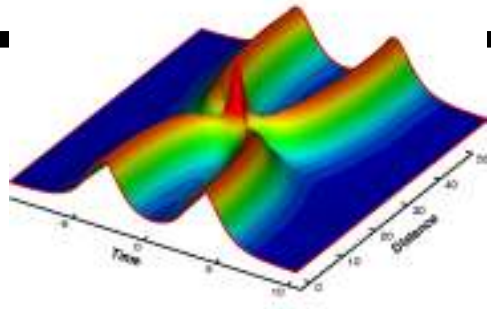
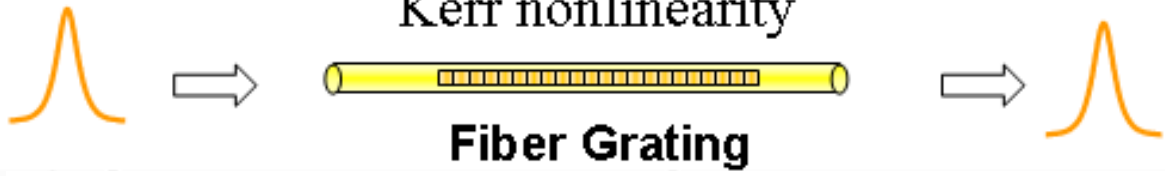
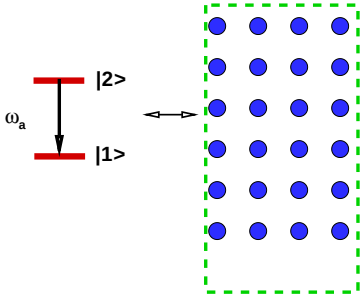
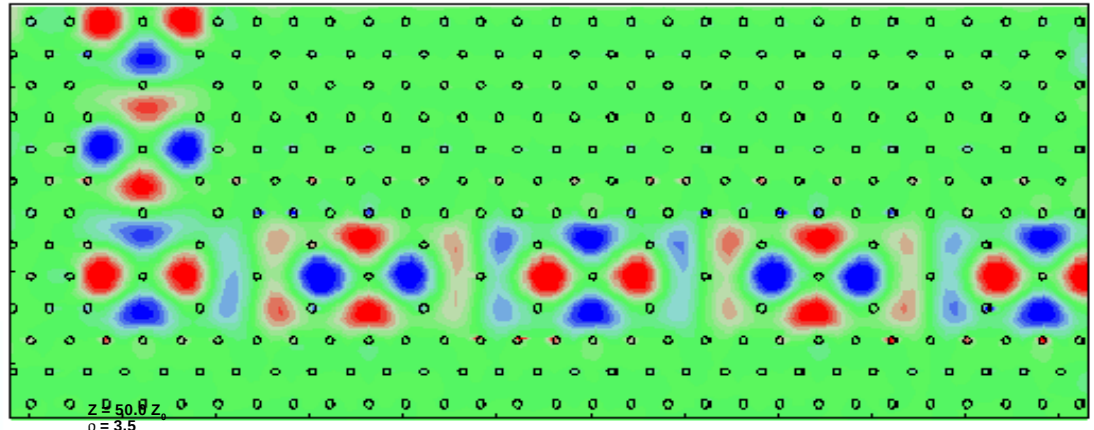
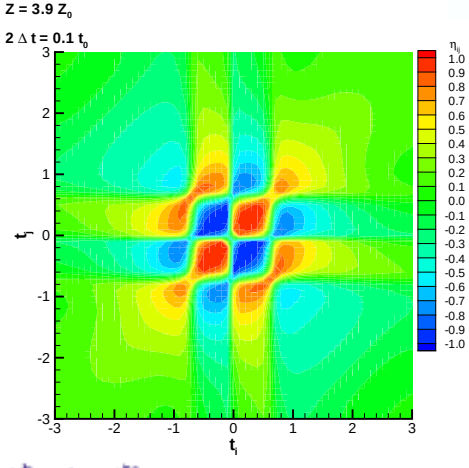
Research highlights at IPT/NTHU

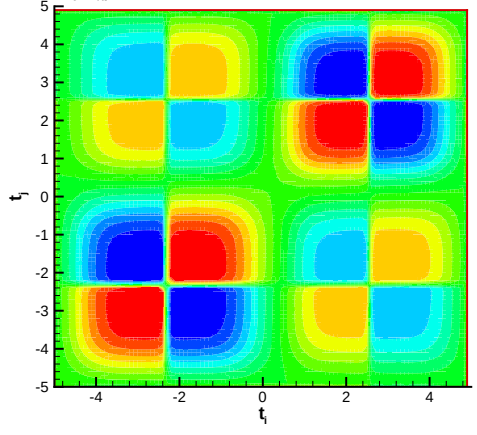


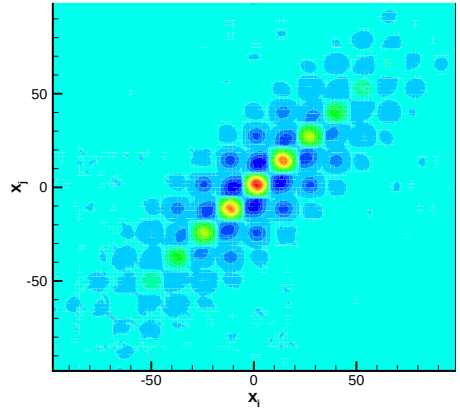












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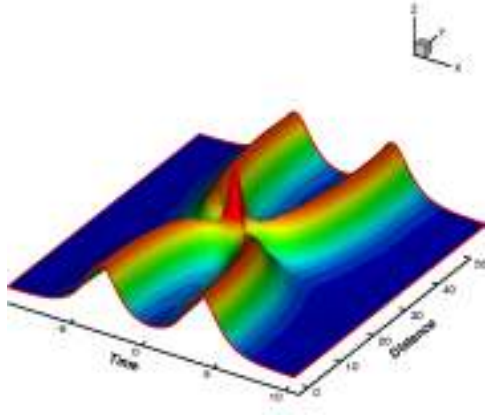
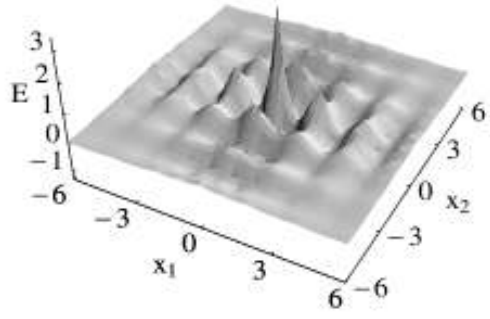
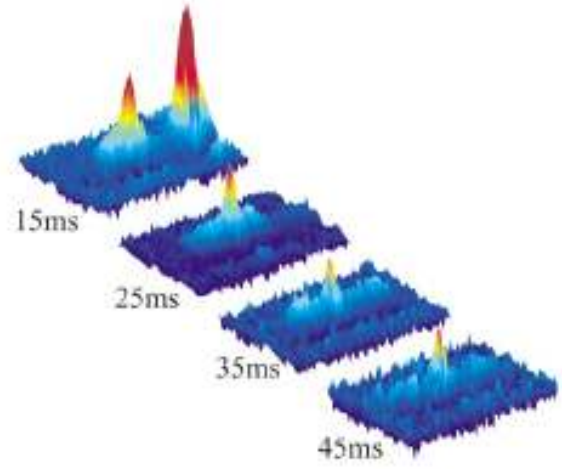
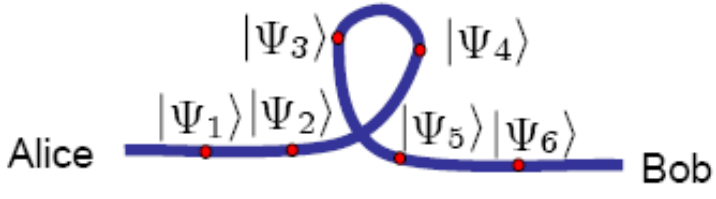
Quantum Optics and Quantum Computers

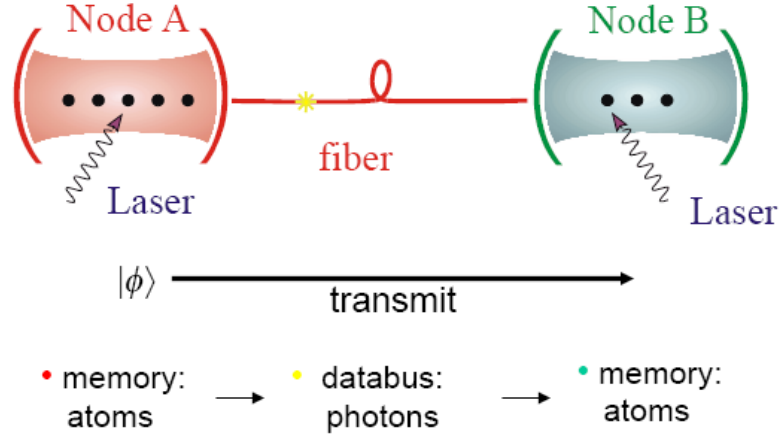






- quantum communication





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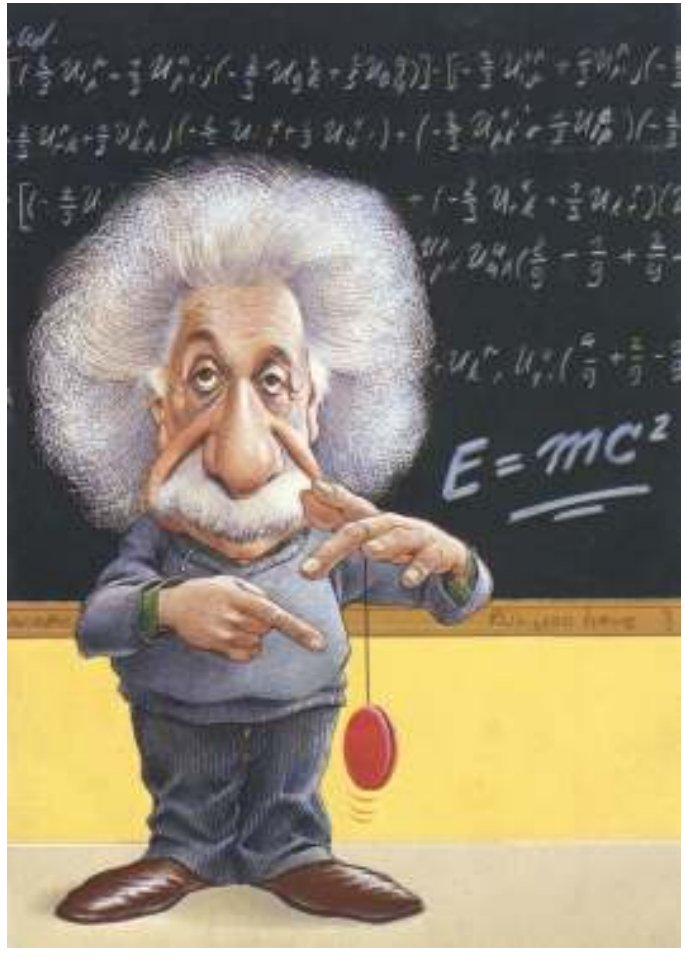

Imagination is more important than knowledge.

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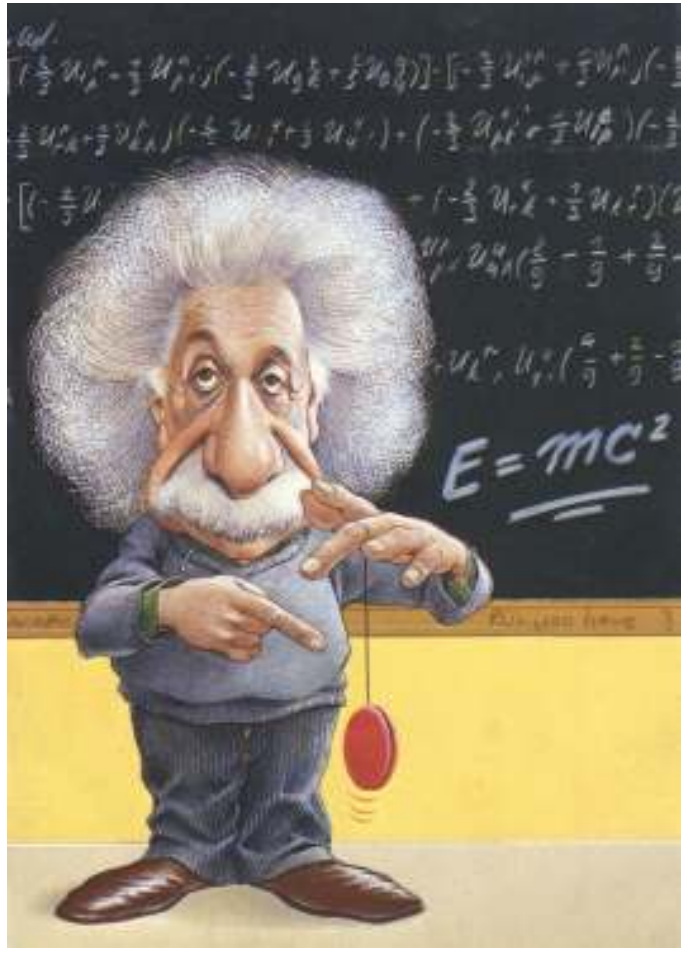

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Welcome to the World of Optics and Have Fun!!