Bharathidasan University

Tiruchirappalli – 620 024, Tamil Nadu, India

Programme: M. Sc., Physics

Course Title : **Lasers and Nonlinear Optics**

Course Code : **22PH401**

Unit IV

Advanced Nonlinear Optics

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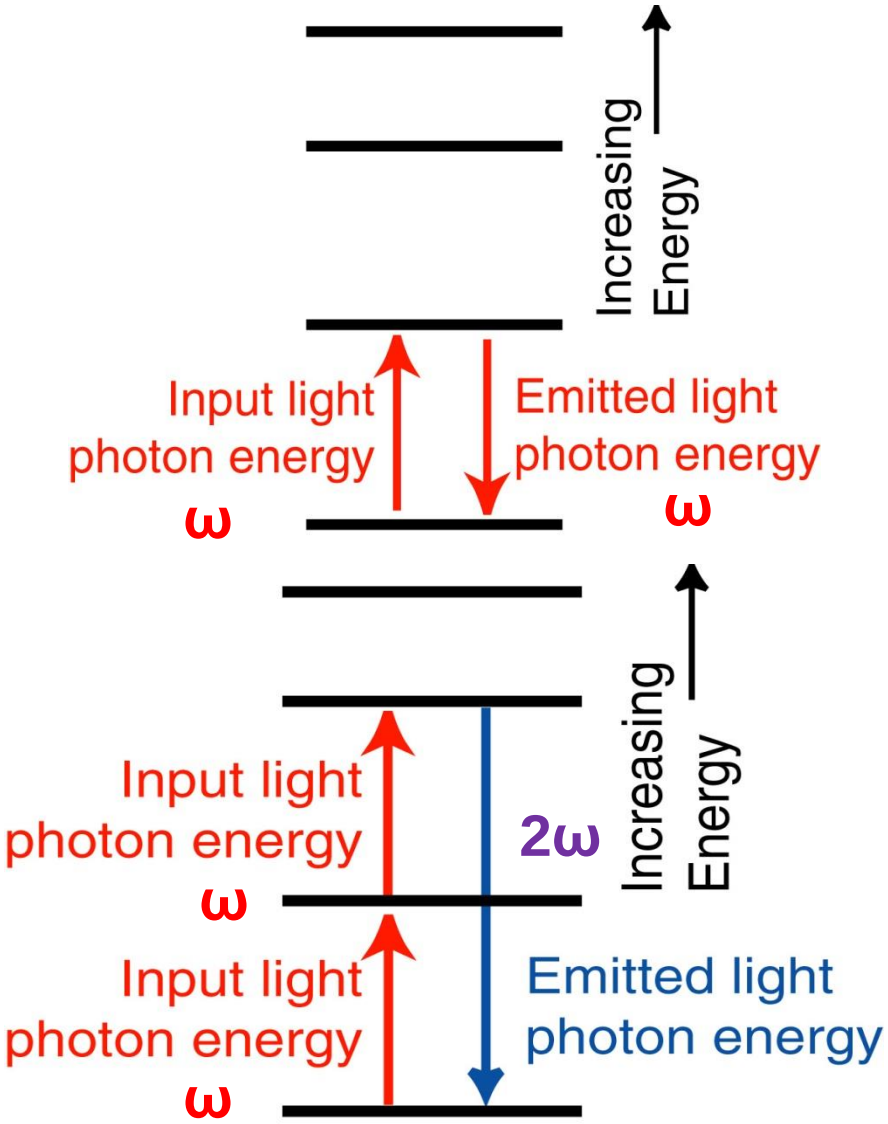
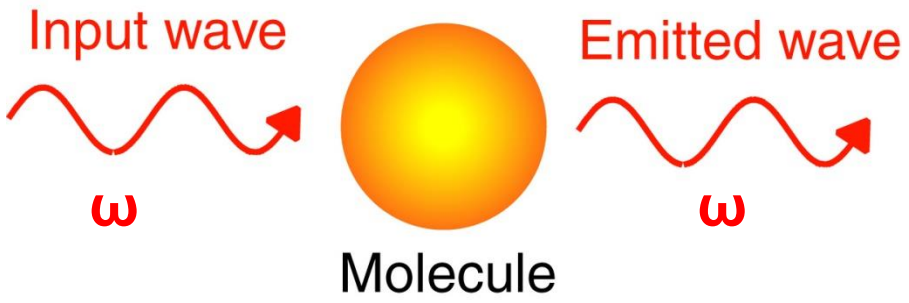
Assistant Professor

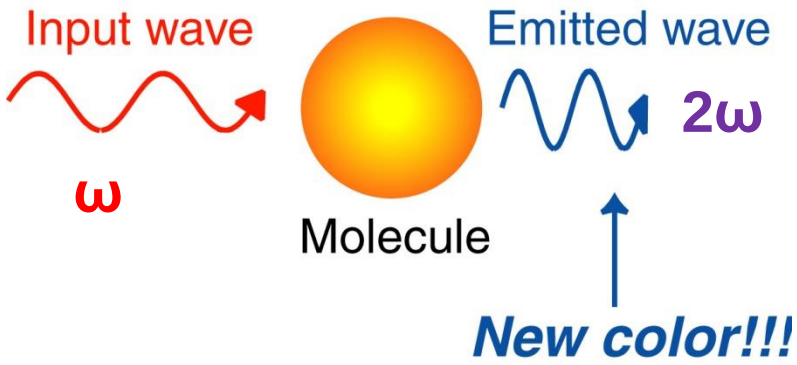
Department of Physics

Is it possible to change the color of a monochromatic light?

Linear and Nonlinear Effect



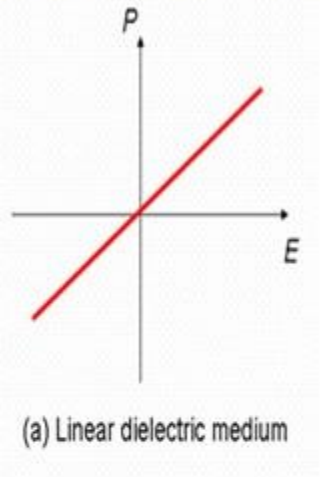




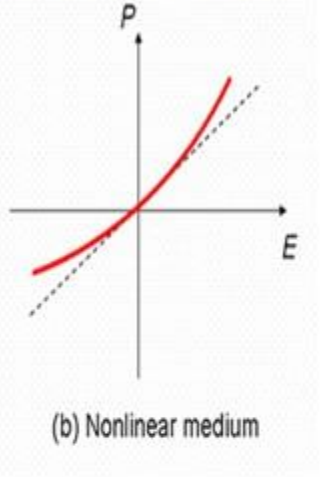
Polarization – Linear and Nonlinear

Linear Polarization

$$\mathbf{P}^{(\mathrm{L})} = \varepsilon_0 \chi^{(1)} \boldsymbol{E}$$



(a) Linear dielectric medium



(b) Nonlinear medium

Nonlinear Polarization

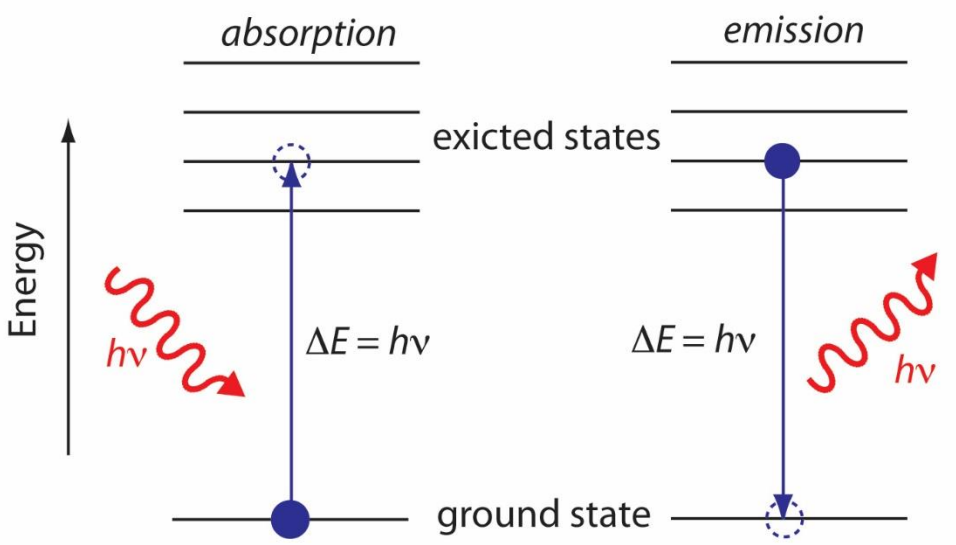
$$\mathbf{P} = \varepsilon_0 \left(\chi^{(1)} \boldsymbol{E} + \chi^{(2)} \boldsymbol{EE} + \chi^{(3)} \boldsymbol{EEE} + \cdots \right)$$

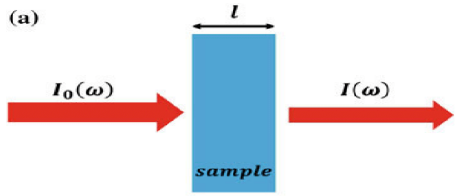
When $\mathbf{E} = \boldsymbol{E_0 \cos(\omega t)}$

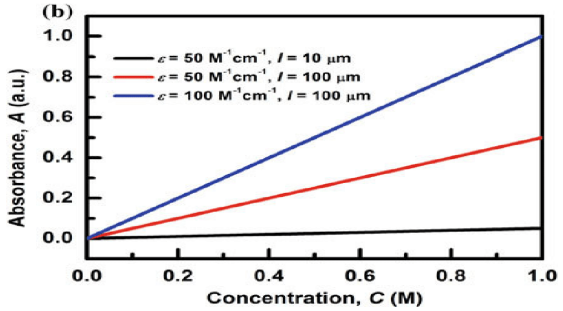
$$= \frac{1}{2} \varepsilon_0 \chi^{(2)} \mathrm{E}_0^2 + \varepsilon_0 \left(\chi^{(1)} + \frac{3}{4} \chi^{(3)} \mathrm{E}_0^2 \right) \mathrm{E}_0 \cos(\omega t)$$

$$+ \frac{1}{2} \varepsilon_0 \chi^{(2)} \mathrm{E}_0^2 \cos(2\omega t) + \frac{1}{4} \varepsilon_0 \chi^{(3)} \mathrm{E}_0^3 \cos(3\omega t) \ldots$$

Absorption – Linear and Nonlinear



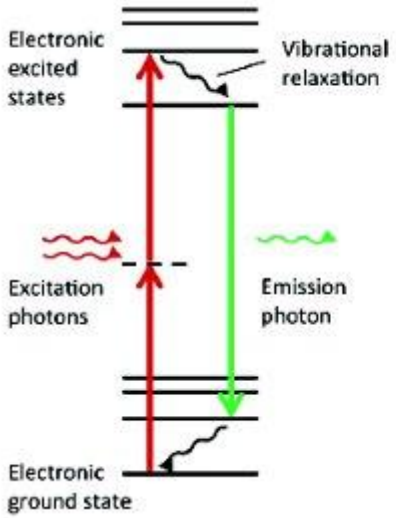


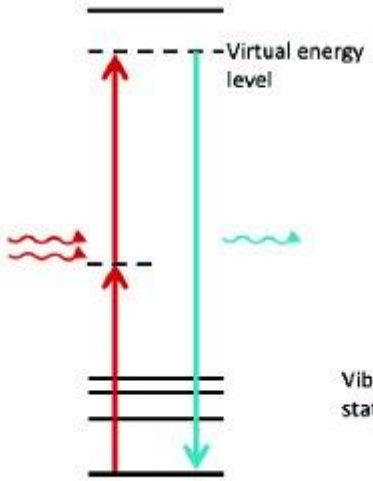


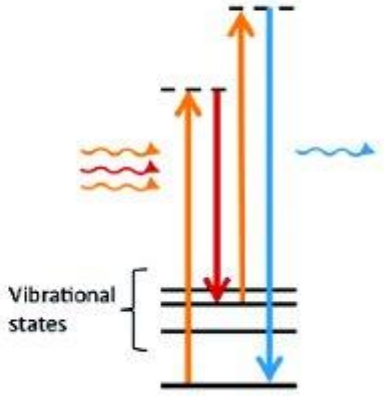
Linear Absorption

Nonlinear Absorption

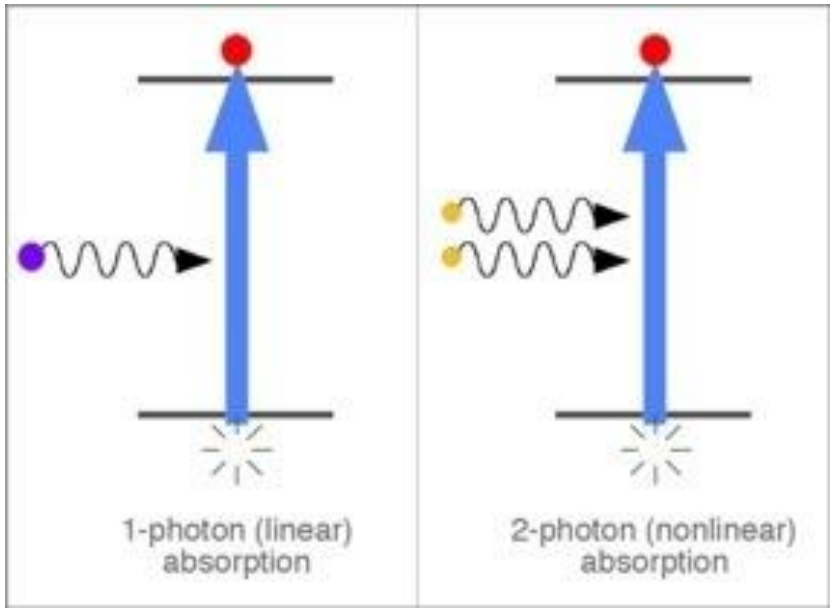
$$\alpha(I) = \alpha_0 + \beta I$$

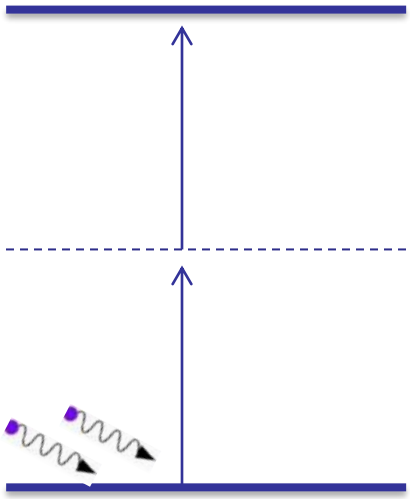




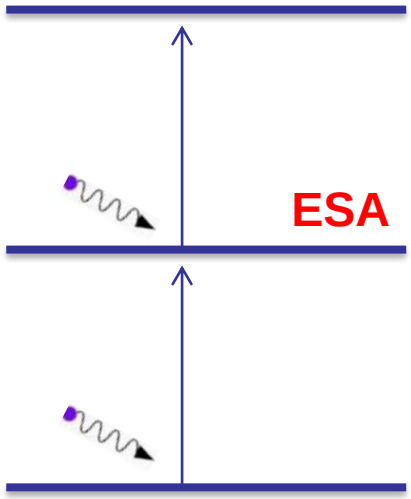


TWO PHOTON ABSORPTION



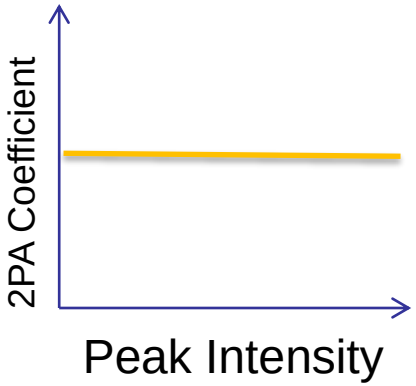


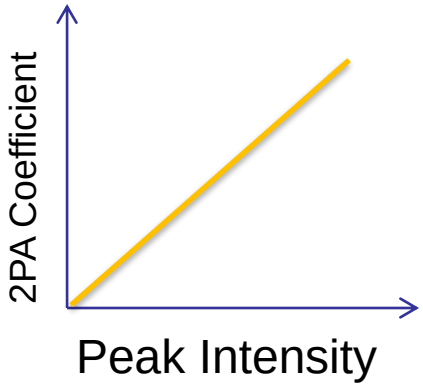
Geniune 2PA



Sequential 2PA

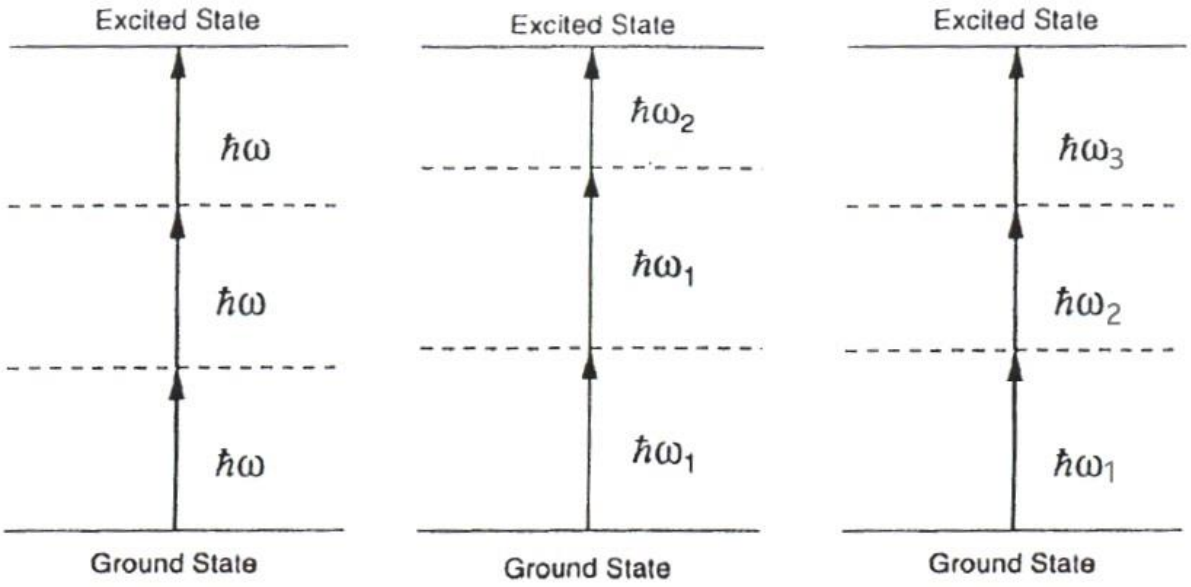
$$\frac{dI}{dz} = -\alpha I - \beta I^2$$





NLA - THREE PHOTON ABSORPTION

NLA-3PA (a) Self (b) Two Beam (c) Three beam



$$\frac{dI}{dz} = -\alpha I - \gamma I^3$$

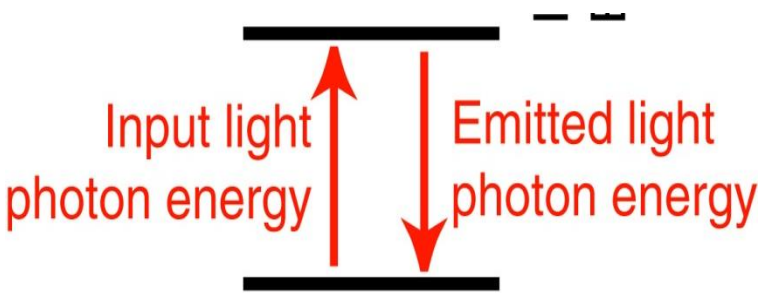
HOW SHG DIFFER FROM THIS PROCESS?

$$P = \varepsilon_0 \chi^{(1)} E$$

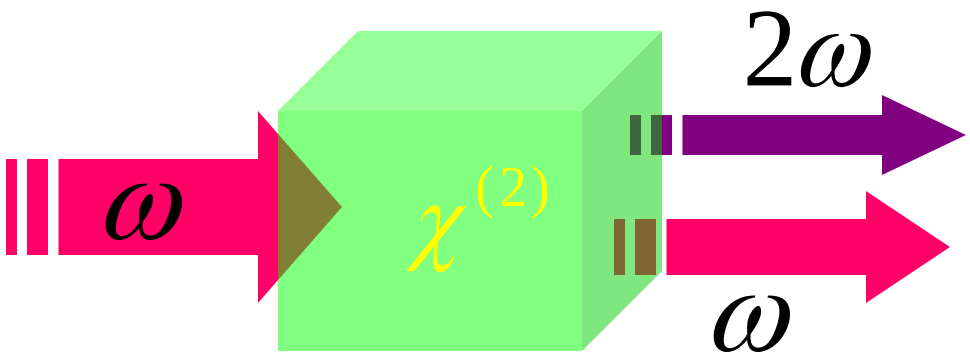
VISIBLE LIGHT

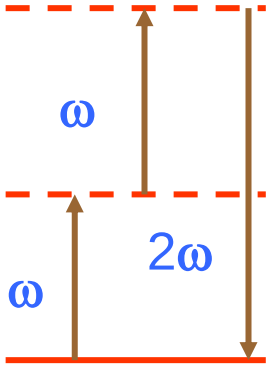
Green Glass Plate

Green Light



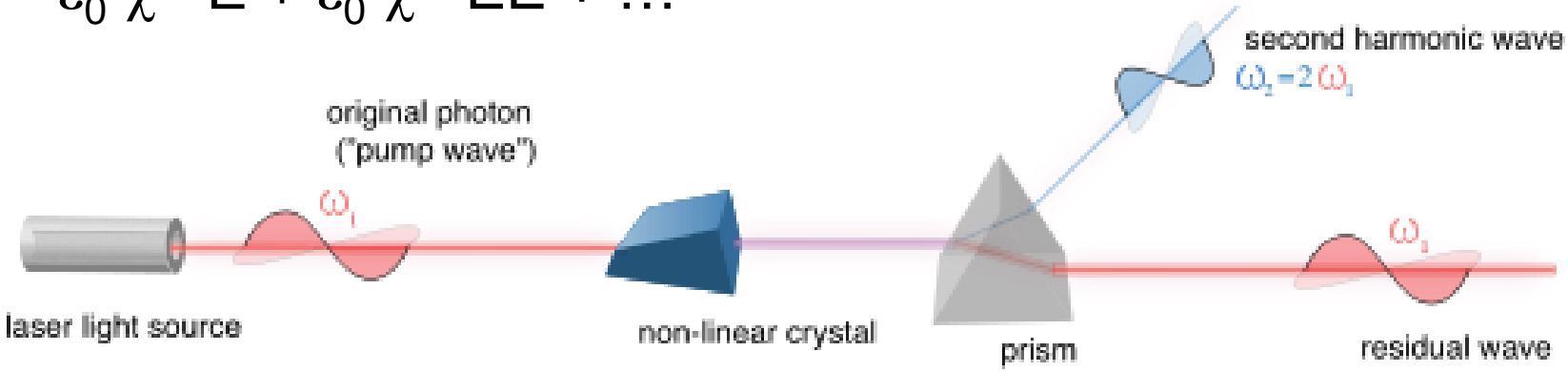
Frequency Doublers





Energy Level Diagram

$P = \varepsilon_0 \chi^{(1)}E + \varepsilon_0 \chi^{(2)}EE + \ldots$



Is it possible to change the color of a monochromatic light?

VOLUME 7, NUMBER 4 PHYSICAL REVIEW LETTERS AUGUST 15, 1961

GENERATION OF OPTICAL HARMONICS*

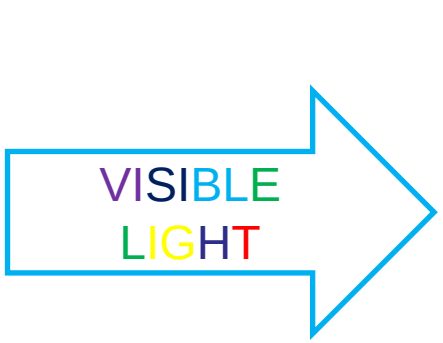
P. A. Franken, A. E. Hill, C. W. Peters, and G. Weinreich
The Harrison M. Randall Laboratory of Physics, The University of Michigan, Ann Arbor, Michigan
(Received July 21, 1961)

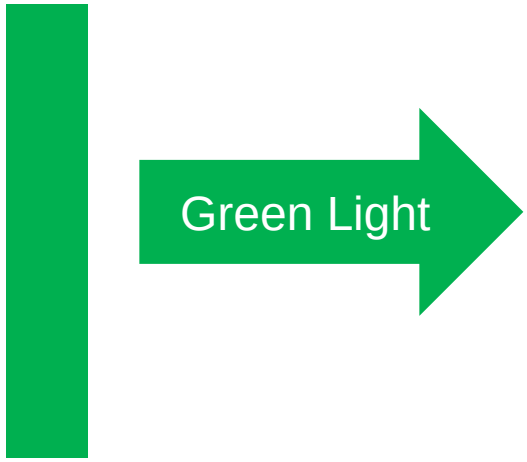
VOLUME 7, NUMBER 4 PHYSICAL REVIEW LETTERS AUGUST 15, 1961

YES!!!

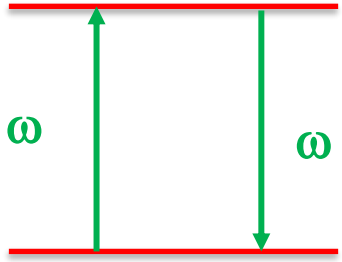
FIG. 1. A direct reproduction of the first plate in which there was an indication of second harmonic. The wavelength scale is in units of 100 A. The arrow at 3472 A indicates the small but dense image produced by the second harmonic. The image of the primary beam at 6943 A is very large due to halation.

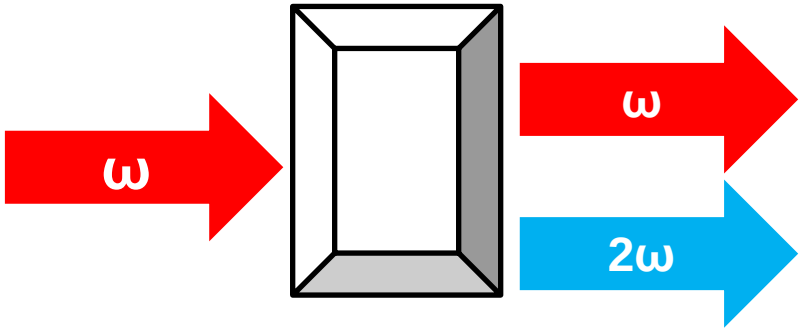
Frequency Doublers



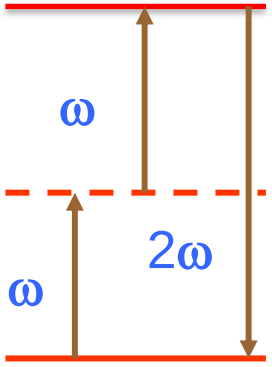


$$P = \varepsilon_0 \chi^{(1)} E$$



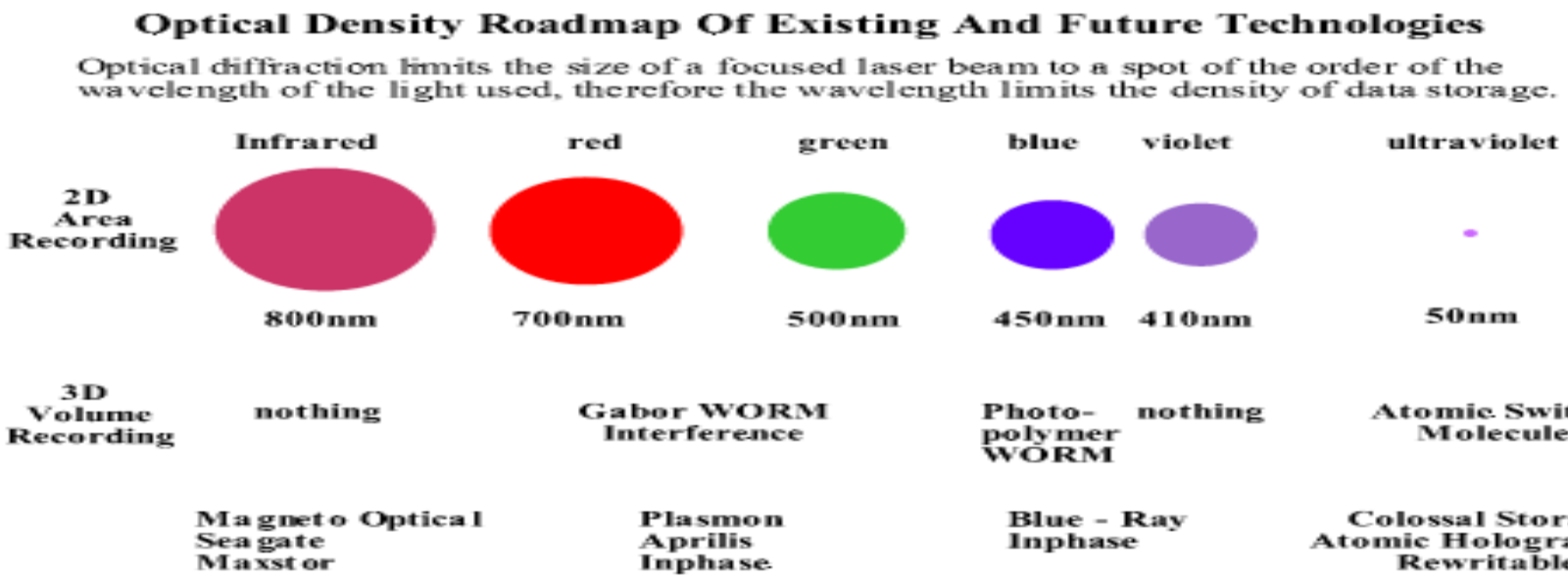


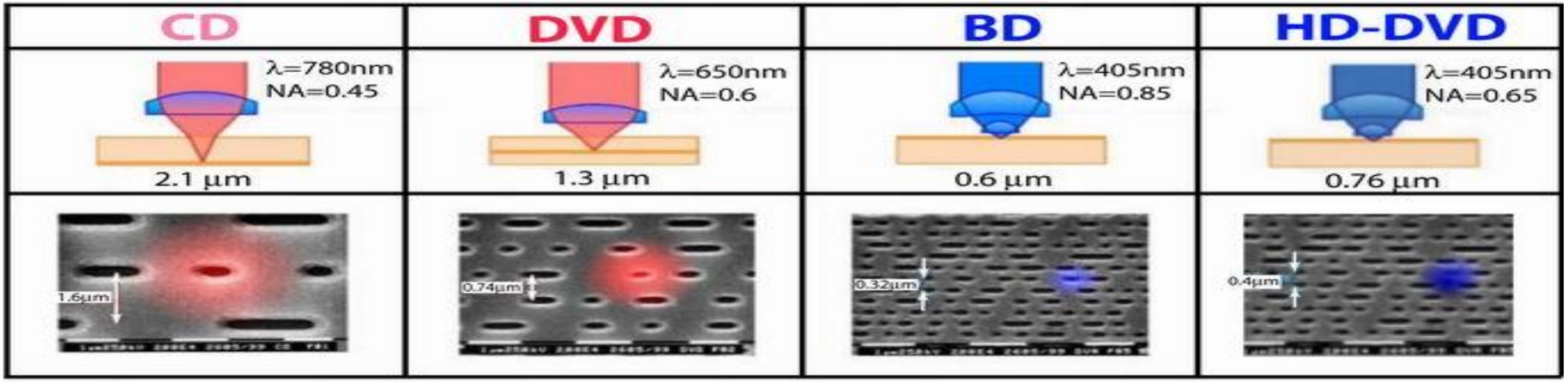
$$P = \varepsilon_0 \chi^{(1)} E + \varepsilon_0 \chi^{(2)} EE$$



Production of SHG from Nd:YAG Laser

Why are the short wavelength lasers in demand?

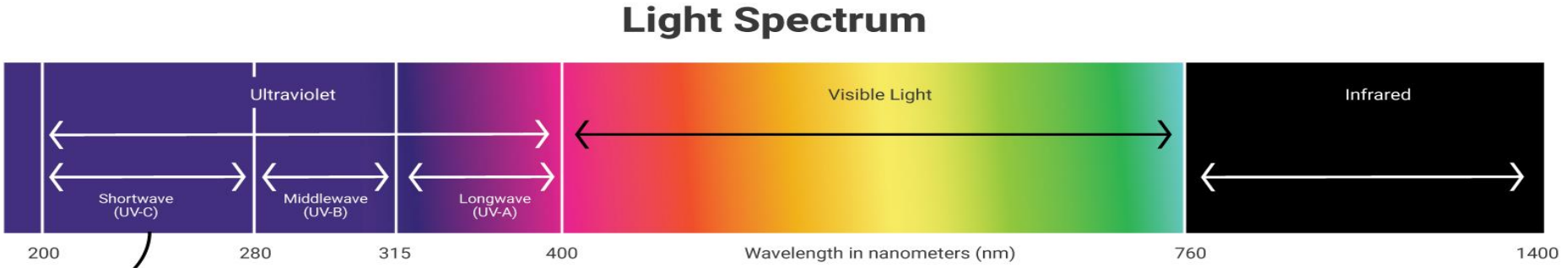


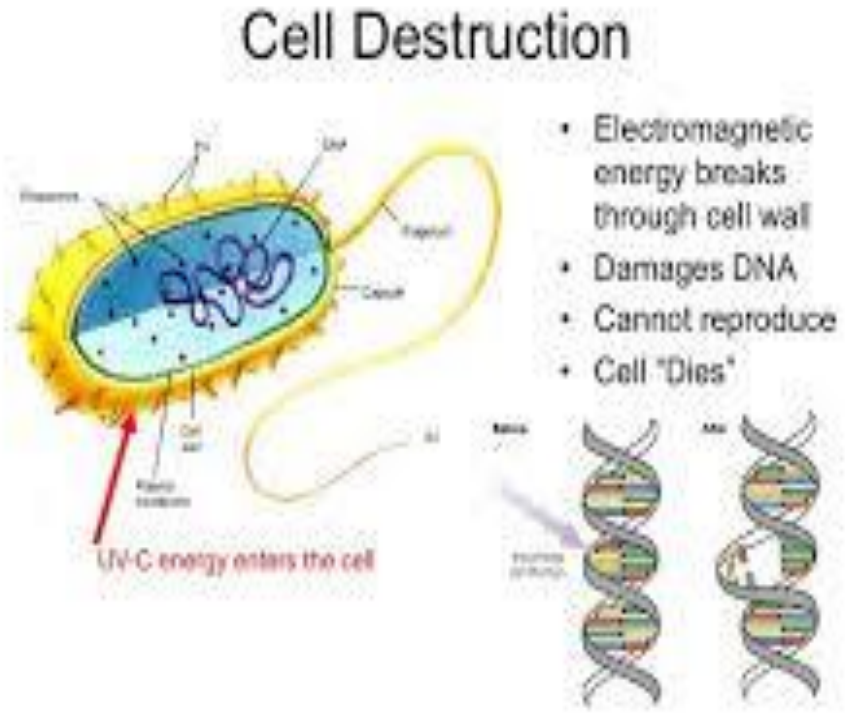


Fighting against Viruses

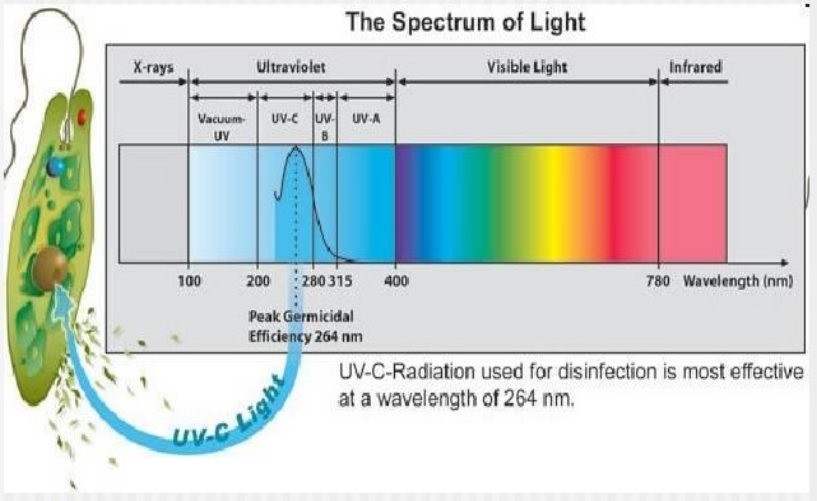
UV Lamp and Sterilizer

Fighting against Viruses





What is UV-C?



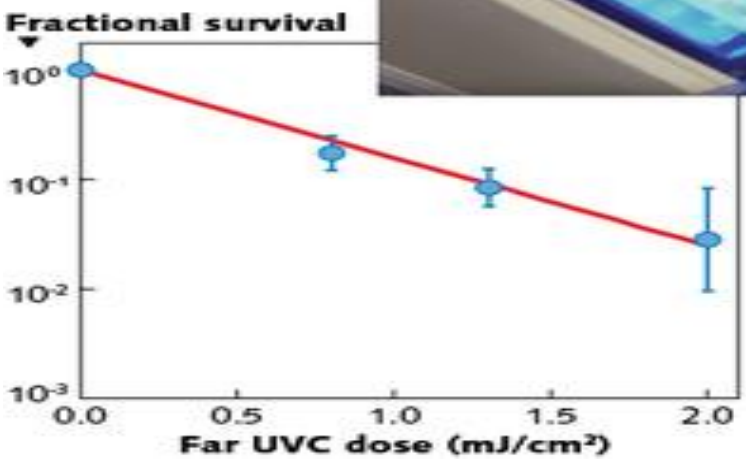
http://www.uvcomparison.com/images/scienceUV-Cspectrum.jpg

UV Light : Need and Challenge

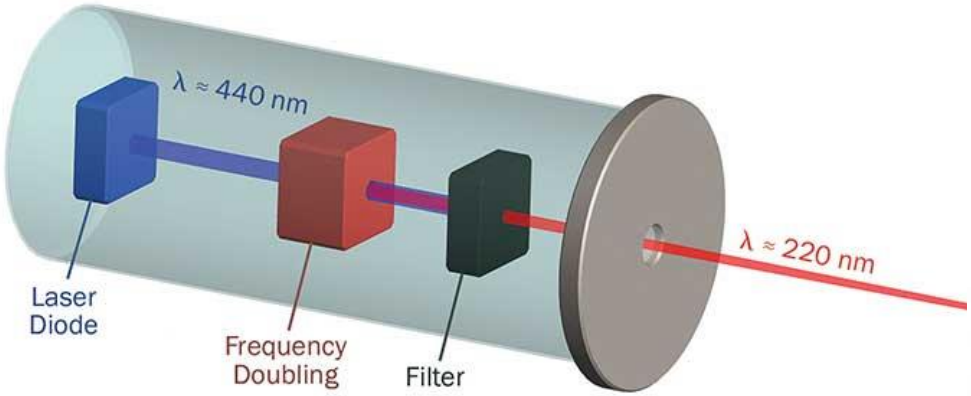
- UV light (200 – 400 nm) can kill bacteria by destroying the molecular bond that hold DNA together
- Conventional germicidal UV light used to decontaminate surgical equipment can cause skin cancer and cataracts
- Far UVc cannot penetrate outer dead cell layer of human skin or tear layer of eye and so it turn harmless

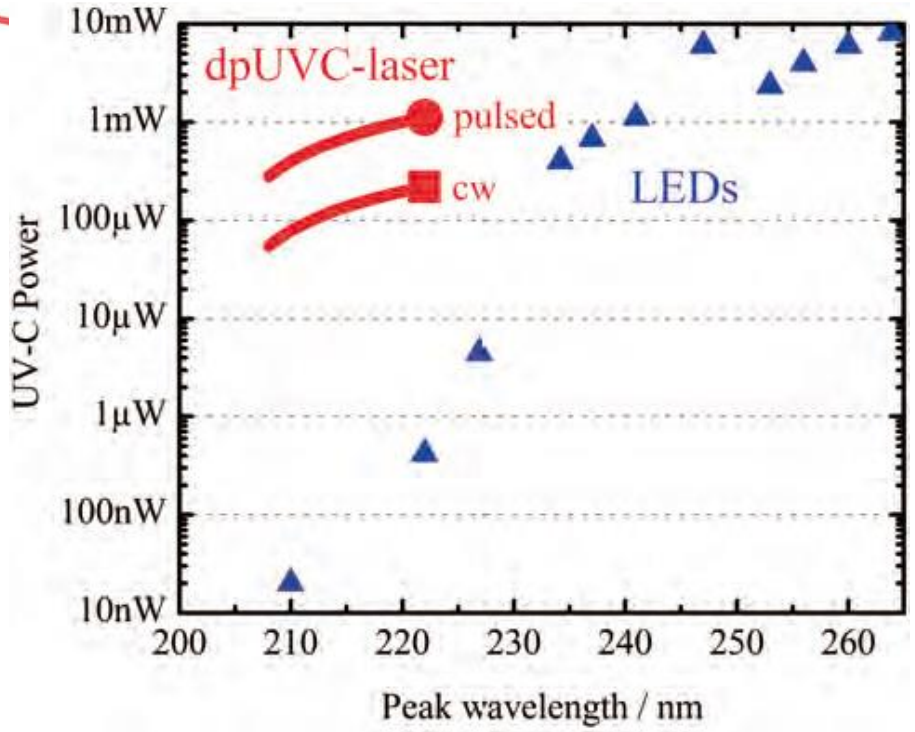
UVc- 220 nm light at 2 mJ/cm^2 killed 95% airborne H1Nl viruses.

But challenge is to produce such light as laser.



UVc Laser Based Steriliser
The Cutting Edge Technology





Books for Study:

1. **K.R. Nambiar**, Lasers: *Principles, Types and Applications* (New Age Inter-national Publishers Ltd, New Delhi, 2014).
2. **B.B. Laud**, *Lasers and Nonlinear Optics,* 3rd Edn. (New Age International Pvt. Ltd., New Delhi, 2011).
3. **Ralf Menzel**, *Photonics* (Springer-Verlag Berlin Heidenberg, New York, 2007)

Books for Reference

1. **Richard L. Sutherland**, *Handbook of Nonlinear Optics*, (Marcel Decker Inc, New York, 2003)
2. **R.W. Boyd**, *Nonlinear Optics, 2nd* Edn. (Academic Press, New York, 2003)
3. **W.T. Silfvast**, *Laser Fundamentals* (Cambridge University Press, Cambridge, 2003)
4. **Y.R. Shen**, *The Principles of Nonlinear Optics*, (Wiley & Sons, New Jersey, 2003)