Second Harmonic Generation Or Doubling Frequency

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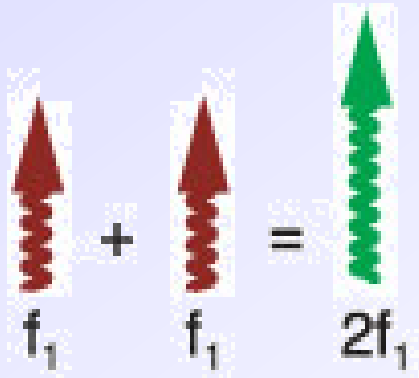
Introduction –

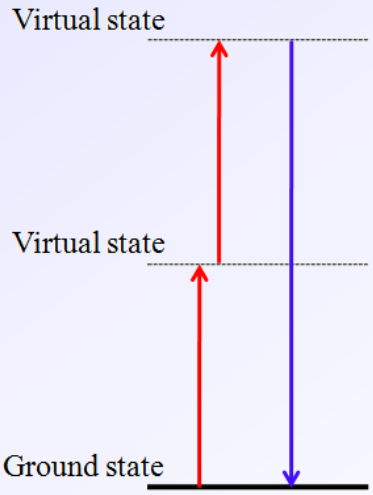
- Second harmonic generation (SHG) is a nonlinear optical process, where two photons of same frequency interact with a nonlinear material to give output photon of double frequency or twice the energy of incident photons (or half the wavelength).

- Nonlinear optical process in the branch of optics which describes the behaviour of light interacting with nonlinear media, that is the media where dielectric polarization P, responds non-linearly with electric field E of the light.

- SHG also known as frequency doubling. $P(2\omega) = \epsilon_{\circ} x^{(2)} E^2(\omega)$

- Second order non-linear susceptibility (degree of dielectric polarization) of a medium characterizes its tendency to cause SHG.





Energy level scheme of SHG process

Ref: https://en.wikipedia.org/wiki/Second-harmonic_generation

History –

❖ SHG was first demonstrated by Peter Franken, A. E. Hill, C. W. Peters, and G. Weinreich at the University of Michigan, Ann Arbor, in 1961. Ruby laser of 694 nm wavelength was allowed to interact with quartz crystal to generate 347 nm output light.

❖ The formulation of SHG was initially described by N. Bloembergen and P. S. Pershan at Harvard in 1962. Using Maxwell's equations they explained light interaction with non-linear medium

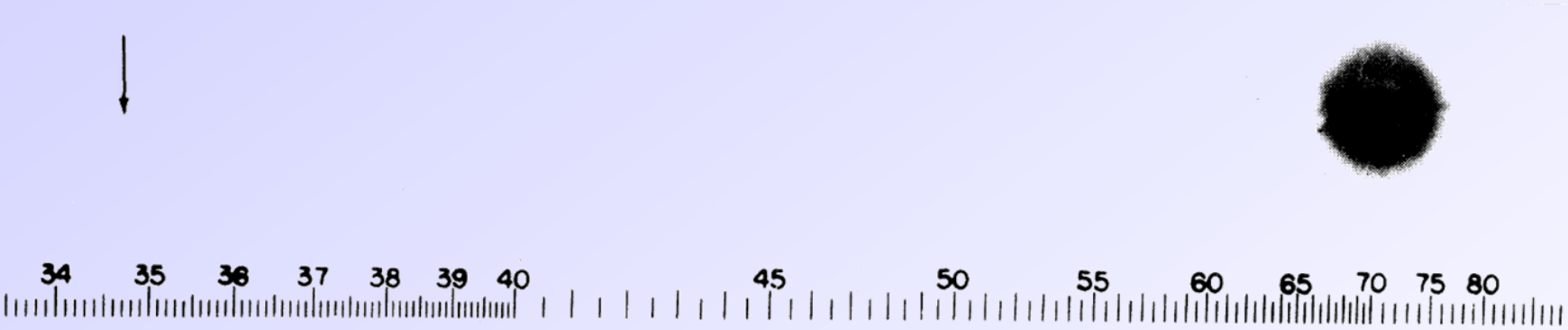


FIG. 1. A direct reproduction of the first plate in which there was an indication of second harmonic. The wavelength scale is in units of 100 A. The arrow at 3472 A indicates the small but dense image produced by the second harmonic. The image of the primary beam at 6943 A is very large due to halation.

DOI: https://doi.org/10.1103/PhysRevLett.7.118

Experimental set-up and working –

- The light source is a high powered pulsed laser system.
- The laser light is linearly polarized and directed towards the non-linear optical medium (usually a crystal) with careful alignment to obtain phase matching.
- The generated second harmonic is separated from the light source by filters and a monochromator.
- The subsequent measurements are done by an electronic photon counting set up.

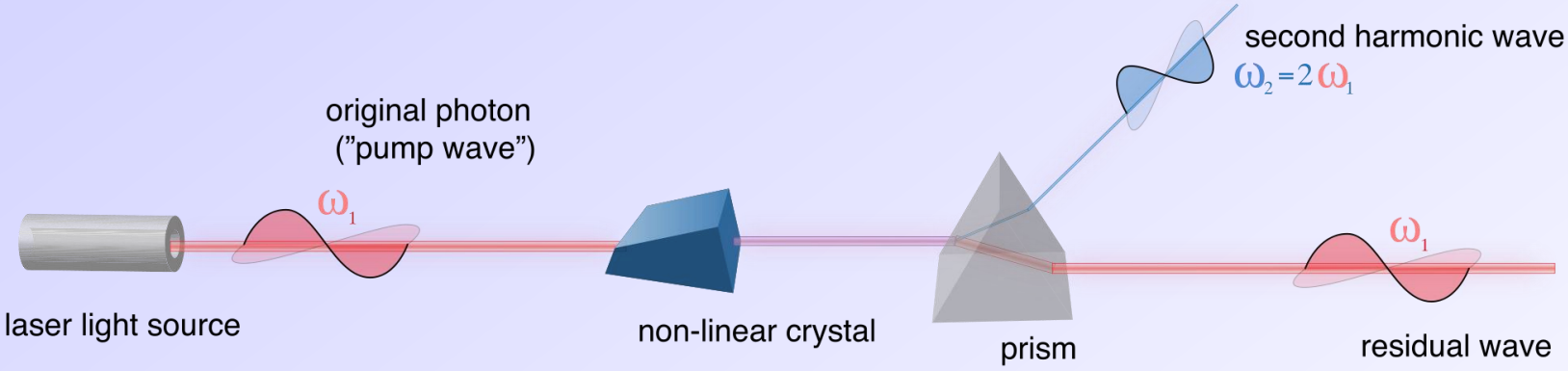


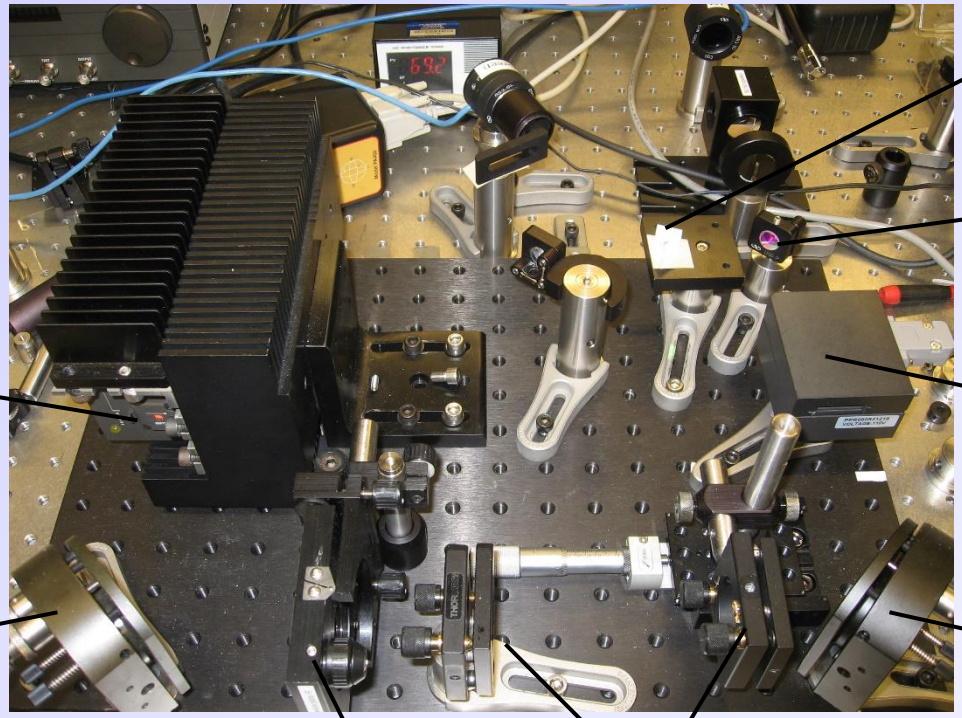
Diagram of the optical path of SHG

Types of SHG –

There are three types of SHG namely type 0, type I, type II.

1. In Type 0 SHG two photons having extraordinary polarization with respect to the crystal will combine to form a single photon with double the frequency/energy and extraordinary polarization.
2. In Type I SHG two photons having ordinary polarization with respect to the crystal will combine to form one photon with double the frequency and extraordinary polarization.
3. In Type II SHG, two photons having orthogonal polarizations will combine to form one photon with double the frequency and extraordinary polarization.

SHG Apparatus – An example of Nd-YAG lasers (green 532 nm) from infrared lasers (1064 nm)

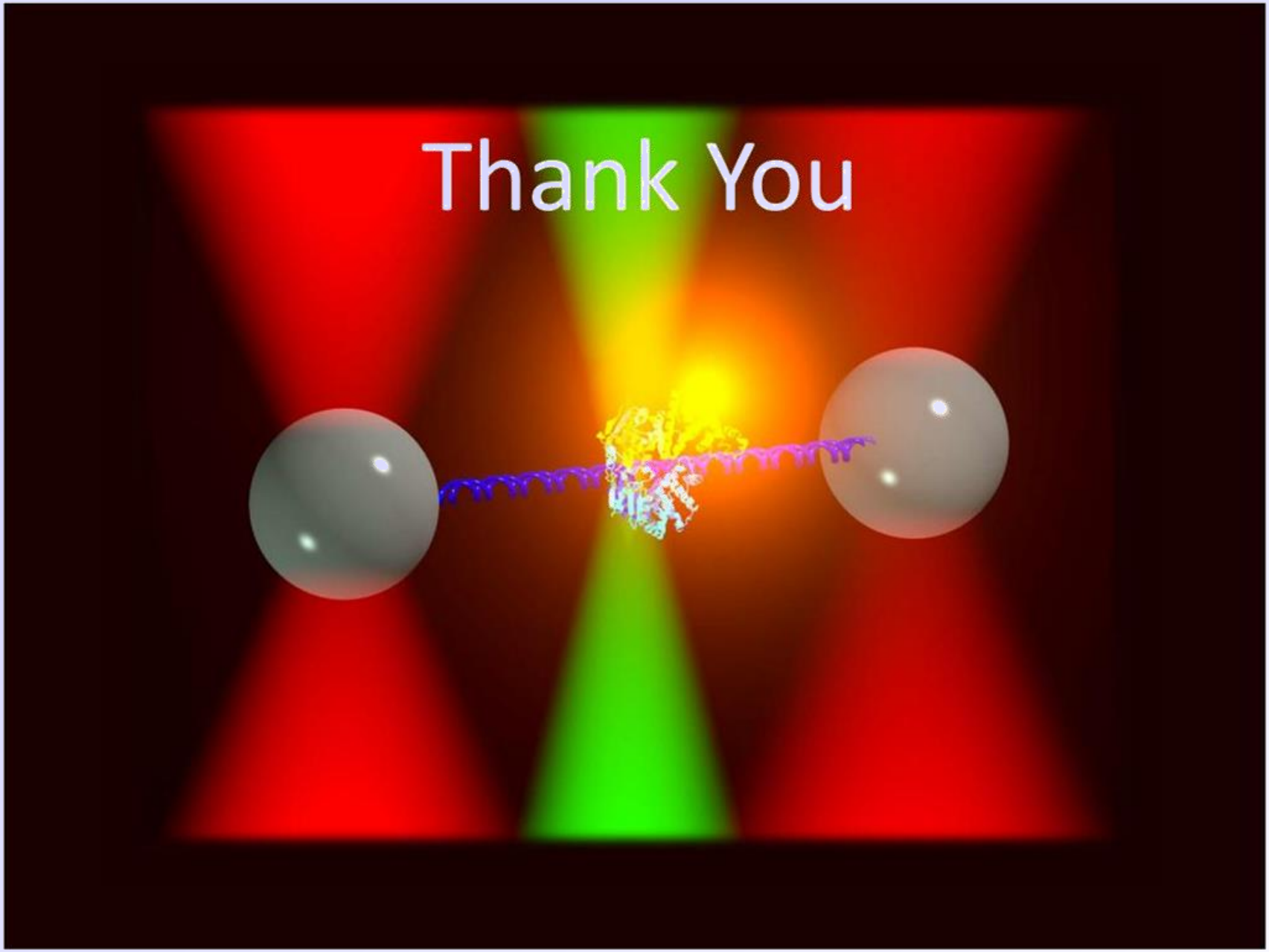


Ref: Diana Parno, Hall A Parity Collaboration Meeting, May 17, 2007

Applications –

Some of the typical applications of second harmonics generation are listed below:

- Microscopy
- Study of biological structures
- Lasers – generating different color laser beams
- Study of surface chemistry


Thank You