50th Anniversary "Nonlinear Optics" East-West Reunion

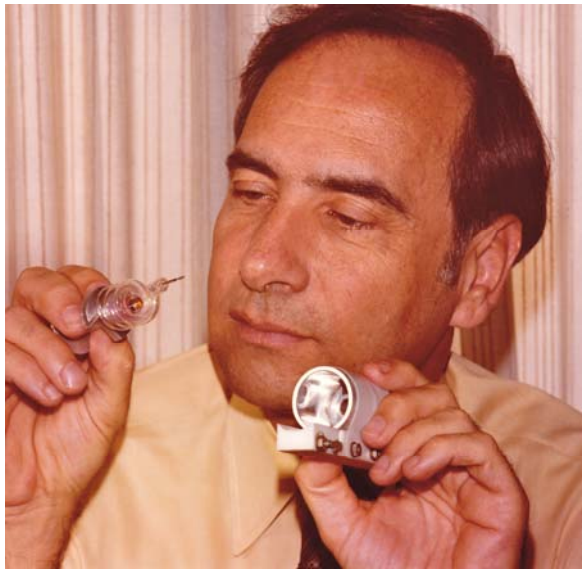
Suzdal

September 21-23, 2011

Gérard Mourou

Institut Lumière Extrême,

The laser is 51!!



T. Maiman
Hughes Laboratory May 16 1960

The first Optical Nonlinear Effect was observed June 28, 1961 (Alan Hill)

P. A. Franken, A. E. Hill, C. W. Peters, and G. Weinreich, "Generation of optical harmonics," Phys. Rev. Lett. 7(4), 118–119 (1961)

J.A. Armstrong, N. Bloembergen, J. Ducuing and P.S. Pershan , "Interactions between light waves in a nonlinear dielectric," Phys. Rev. 127, 1918–1939, 1962.

Nonlinear Optical Effects

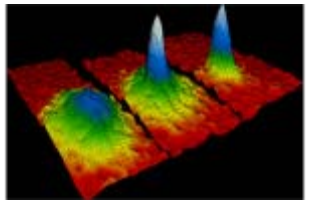
- **Frequency mixing processes**
- Second harmonic generation (SHG),
- Third harmonic generation (THG), generation
- High harmonic generation (HHG), generation of light with frequencies much greater than the original (typically 100 to 1000 times greater)
- Sum frequency generation (SFG)
- Difference frequency generation (DFG),
- Optical parametric amplification (OPA),
- Optical parametric oscillation (OPO),
- Optical parametric generation (OPG),
- Spontaneous parametric down conversion (SPDC),
- Optical rectification (OR), generation of quasi-static electric fields.
- Nonlinear light-matter interaction with free electrons and plasmas[1][2][3][4]

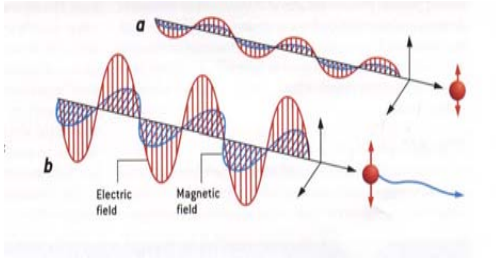
Nonlinear Optical Effects

- **Other nonlinear processes**
- Optical Kerr effect, intensity dependent refractive index (a $\chi^{(3)}$ effect)
- Self-focusing, an effect due to the Optical Kerr effect (and possibly higher order nonlinearities) caused by the spatial variation in the intensity creating a spatial variation in the refractive index
- Kerr-lens modelocking (KLM), the use of Self-focusing as a mechanism to mode lock laser.
- Self-phase modulation (SPM), an effect due to the Optical Kerr effect (and possibly higher order nonlinearities) caused by the temporal variation in the intensity creating a temporal variation in the refractive index
- Optical solitons, An equilibrium solution for either an optical pulse (temporal soliton) or Spatial mode (spatial soliton) that does not change during propagation due to a balance between diffraction and the Kerr effect (e.g. Self-phase modulation for temporal and Self-focusing for spatial solitons).

Laser Physics

Quantum Optics
feV-neV





Relativistic Optics
GeV-TeV

2010 — 1eV — 2010

1960

Atomic, molecular and optical (AMO)Physics

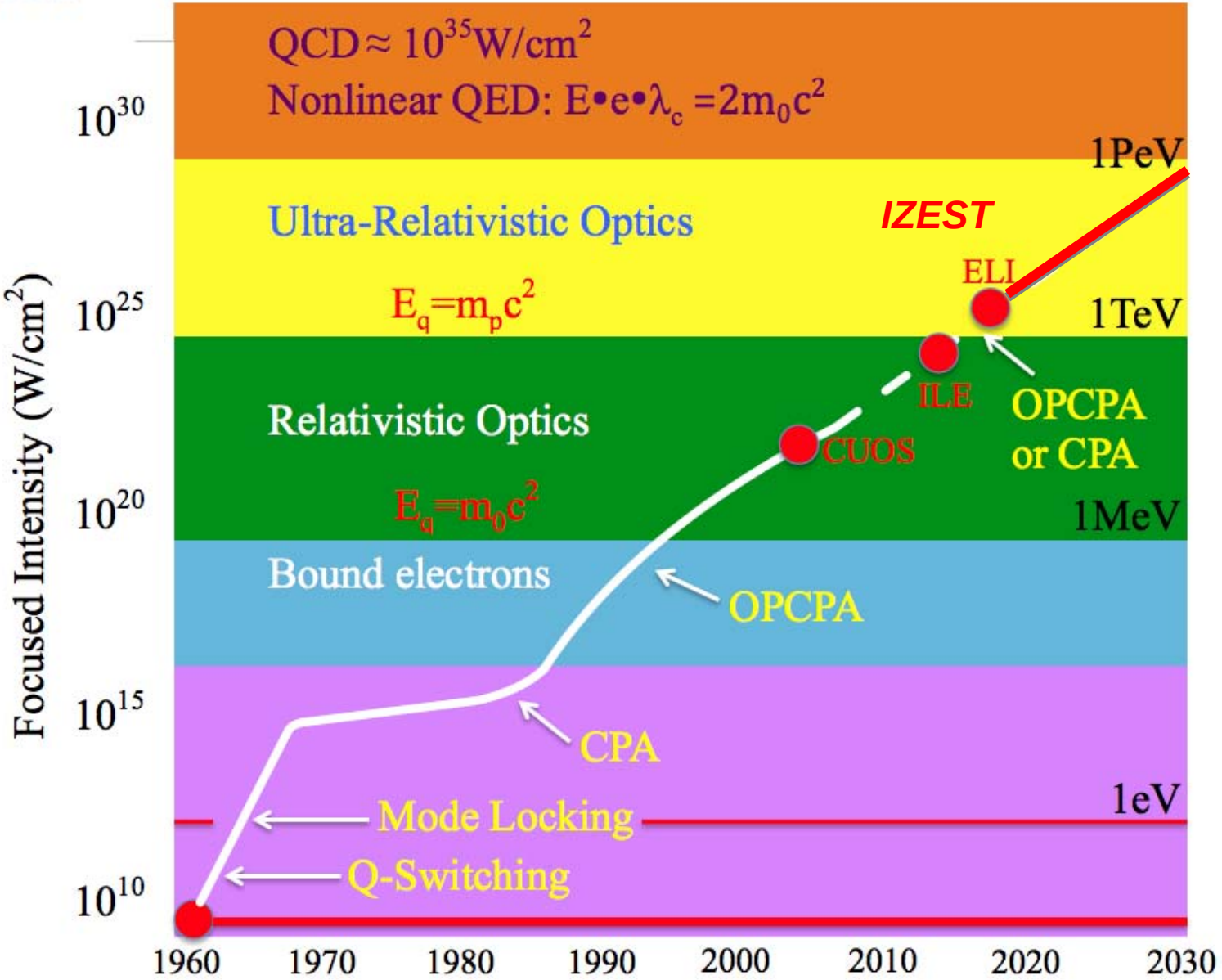
- Metrology
- Condensed-Matter Physics
- Quantum Information Chemistry

Relativistic/ultraRelativistic Optics

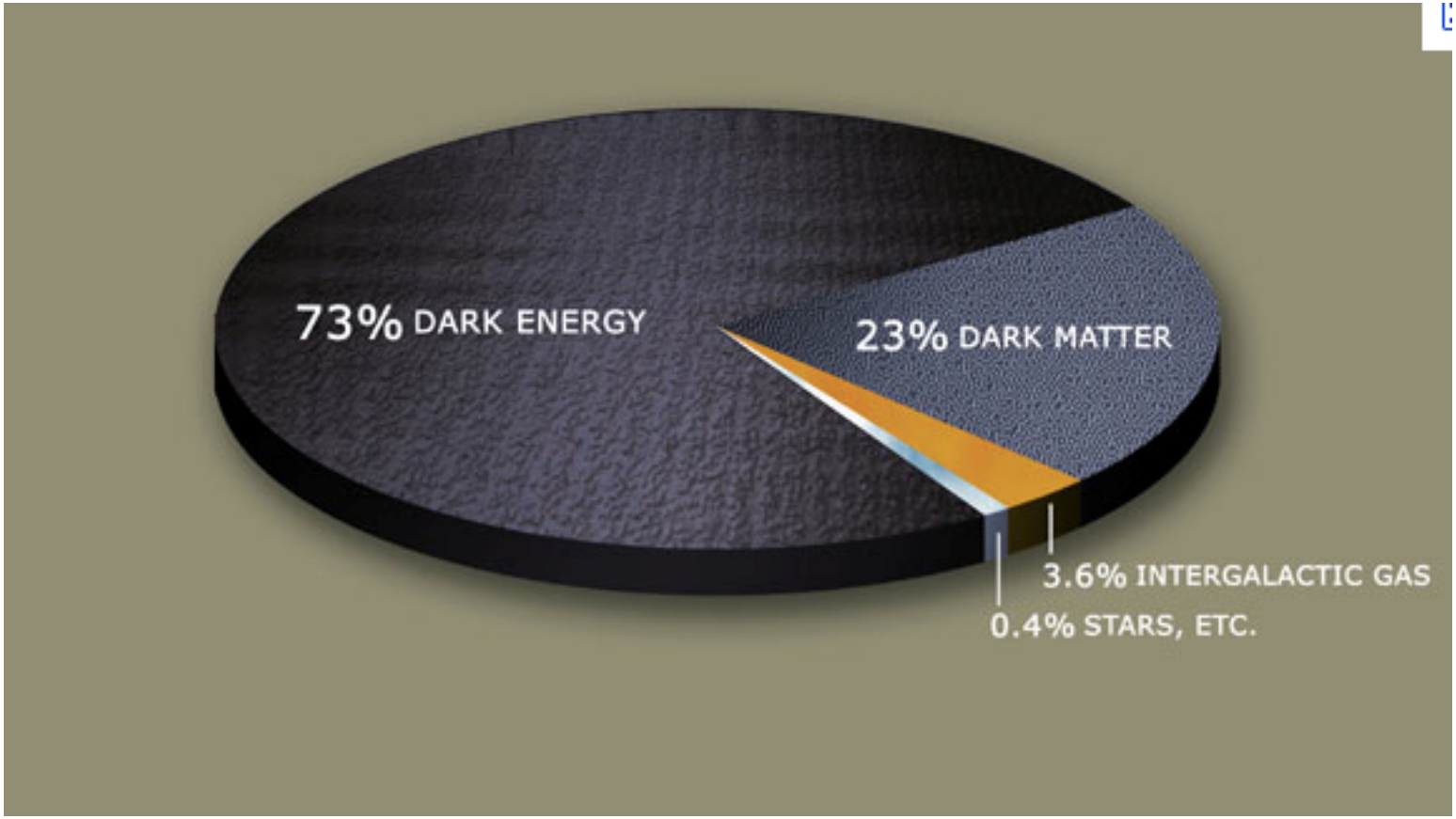
Plasma physics

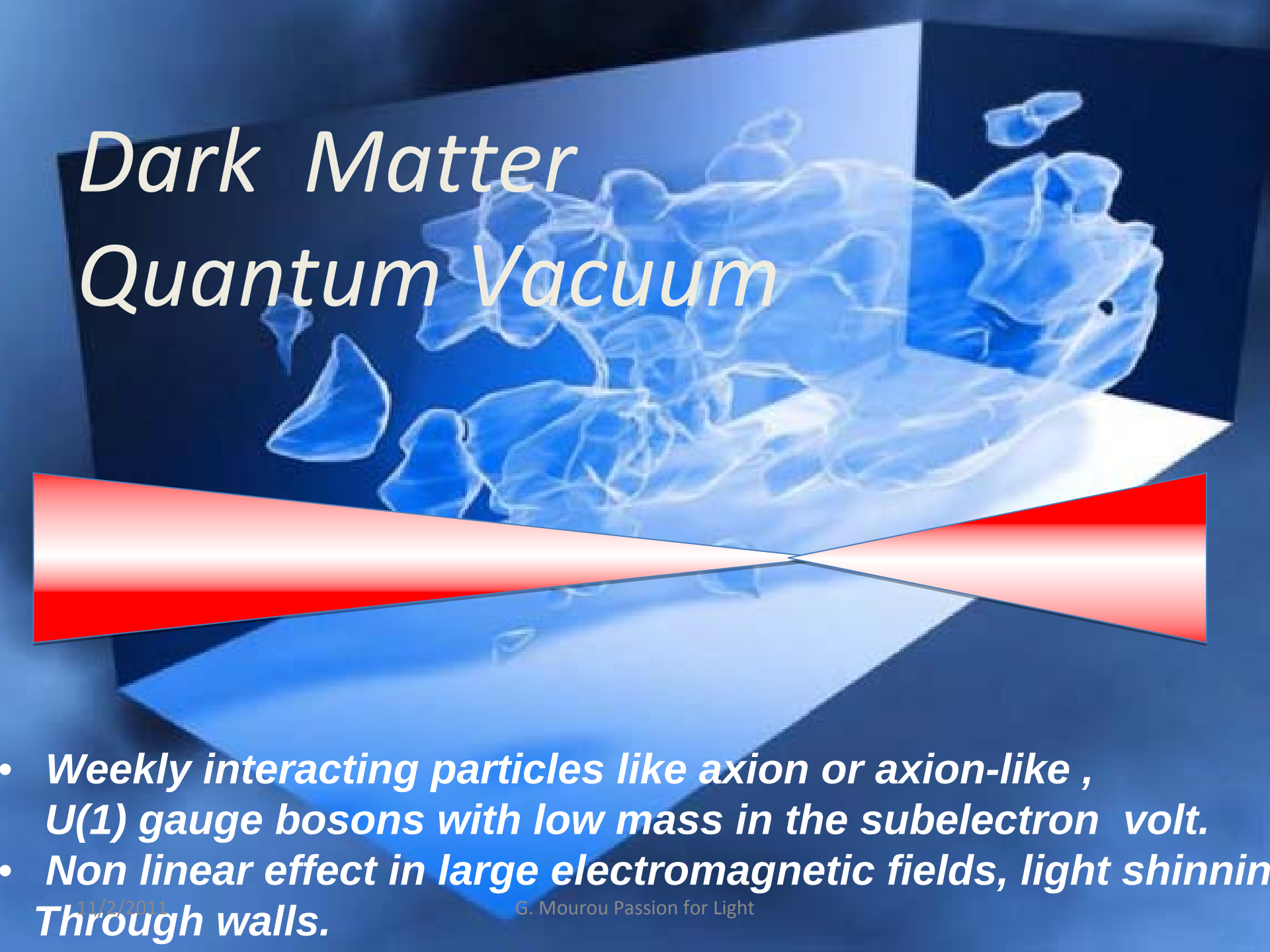
- Accelerator physics
- Nuclear Physics
- Cosmology
- NL QED
- General Relativity
- Extradimension physics

Laser Intensity vs. Years



Dark Matter and Dark Energy





- ***Weekly interacting particles like axion or axion-like , U(1) gauge bosons with low mass in the subelectron volt.***
- ***Non linear effect in large electromagnetic fields, light shinnin***

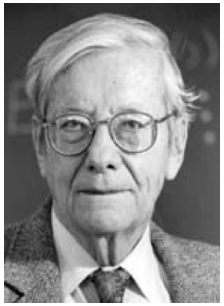
Through walls.

Nonlinear optics

1960

Coulombic Epoch

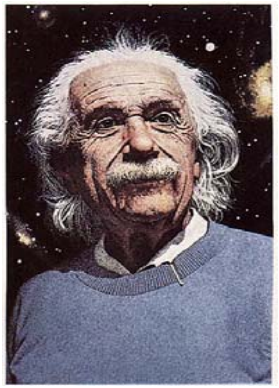
$$E_c = \frac{e}{r_b^{\,2}} = \frac{m^2 e^5}{\hbar^4}$$



1990

RelativisticEpoch

$$E_R = \frac{m_0 c^2}{e\lambda} = \frac{h\nu}{\lambda\!\!\!^{-}_c e}$$



2010

Nonlinear QED

Dark Matter,…

$$E_S = \frac{2m_0 c^2}{\lambda\!\!\!^{-}_C e}$$