ELECTROMAGNETICALLY INDUCED TRANSPARENCY (EXPERIMENTAL)

Golden Words

The purpose of education is to learn, build character and spread knowledge, not to start experiments and publish papers.

Quoted
Dr Sabieh Anwar

Overview

- What is Electromagnetically Induced Transparency?
- The Experimental Setup
  - Basic Setup
  - Lasers to be used
- Variables to be Controlled
  - Wavelength
  - Intensity
  - Beam Size and Shape
  - Polarization
  - Quantum Phase
- Future Prospects and Applications

What is ?

- It is a relative term.
- It depends on the wave and the medium in question.

Transparency

↓

Refractive Index

↓

Speed of Light

WIKEPEDIA VS BARRY SANDERS

- 'Wikepedia' says that for transparency a photon has to be:-
  - Fully absorbed by the electron (resonant transition)
  - Re-emitted by spontaneous emission
  - Process continues till it reaches the other side.

- Barry Sanders absolutely rubbished the idea saying that transparency is simply the phenomenon in which a photon doesn't find any resonant transitions in the material under consideration and so it passes right through it.

Wikepedia alters its Statement

- At the micro-scale, an electromagnetic wave's phase speed is slowed in a material because the electric field creates a disturbance in the charges of each atom (primarily the electrons) proportional to the electric susceptibility of the medium.
- Similarly, the magnetic field creates a disturbance proportional to the magnetic susceptibility.
- As the electromagnetic fields oscillate in the wave, the charges in the material will be "shaken" back and forth at the same frequency.
- The charges thus radiate their own electromagnetic wave that is at the same frequency, but usually with a phase delay, as the charges may move out of phase with the force driving them.

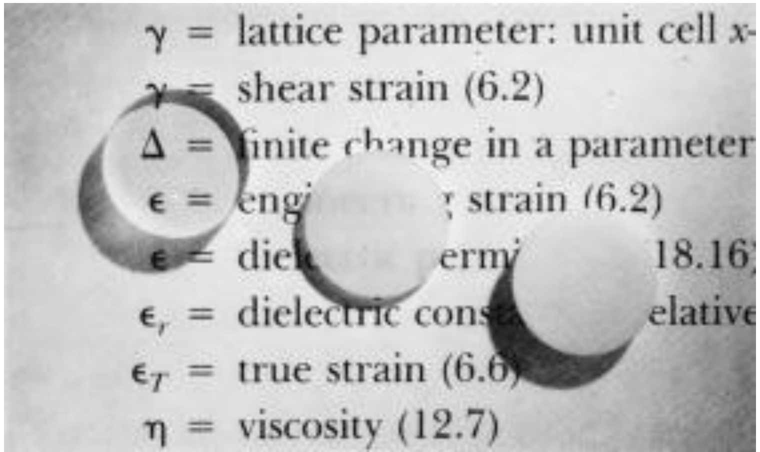
A Materials Scientist Perception of Transparency

All of these specimens are of the same material, aluminum oxide.

The leftmost one is what we call a single crystal, that is, it is highly perfect which gives rise to its transparency.

The center one is composed of numerous and very small interconnected single crystals that the boundaries between these small crystals scatter a portion of the light reflected from the printed page, which makes this material optically translucent.

And finally, the specimen on the right is composed not only of many small, interconnected crystals, but also of a large number of very small pores or void spaces making it opaque.



Time Travel

6 May 2011

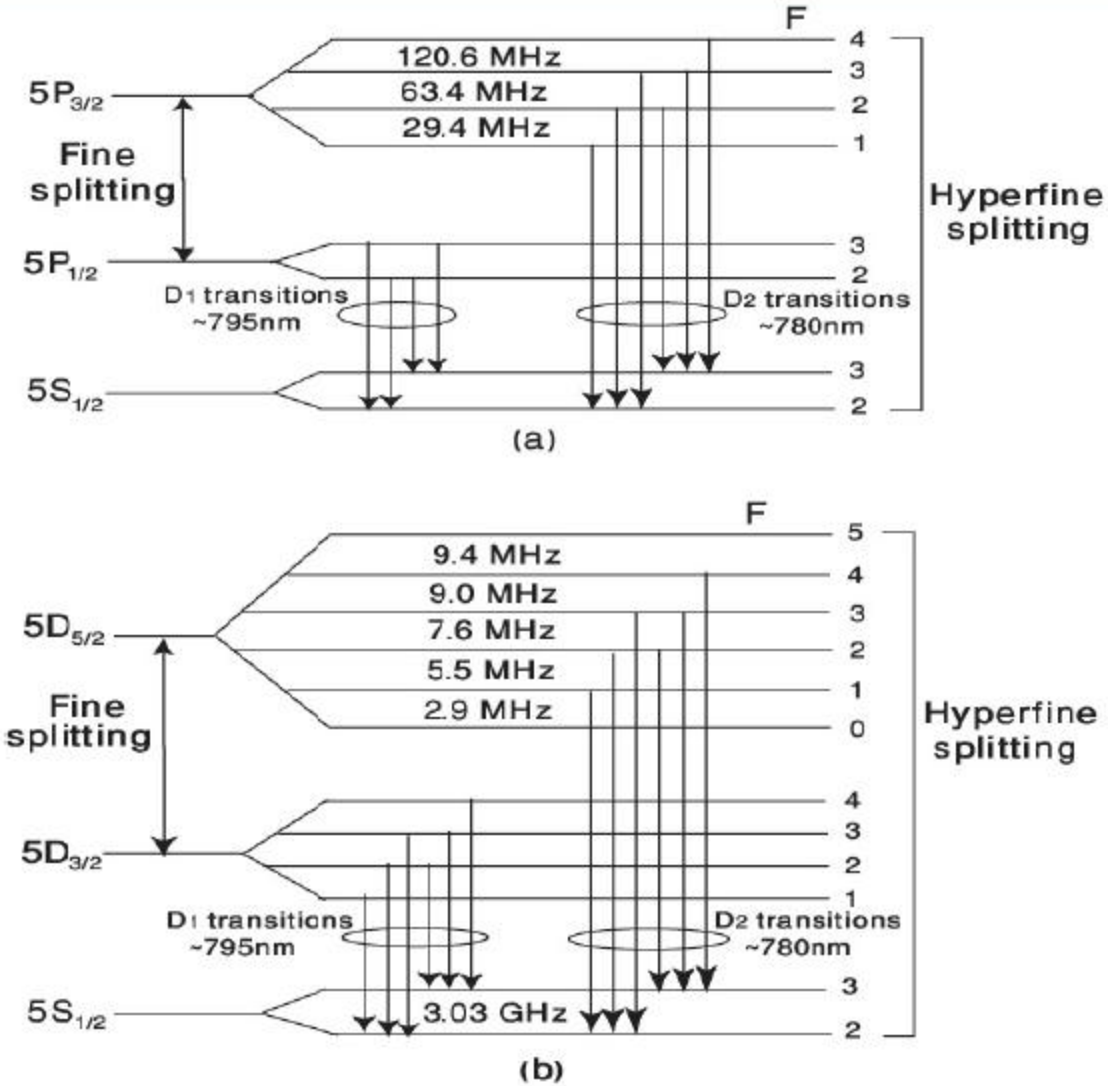
Electromagnetically Induced Transparency

Stolen

- The concept of EIT was first given by Harris et al in 1990. When a strong coupling laser field is used to drive a resonant transition in a three-level atomic system, the absorption of a weak probe laser field can be reduced or eliminated provided the two resonant transitions are coherently coupled to a common state.
- EIT was first observed in lambda type system of strontium vapors using high pulsed laser in 1991.

Energy level diagram of ^{85}Rb

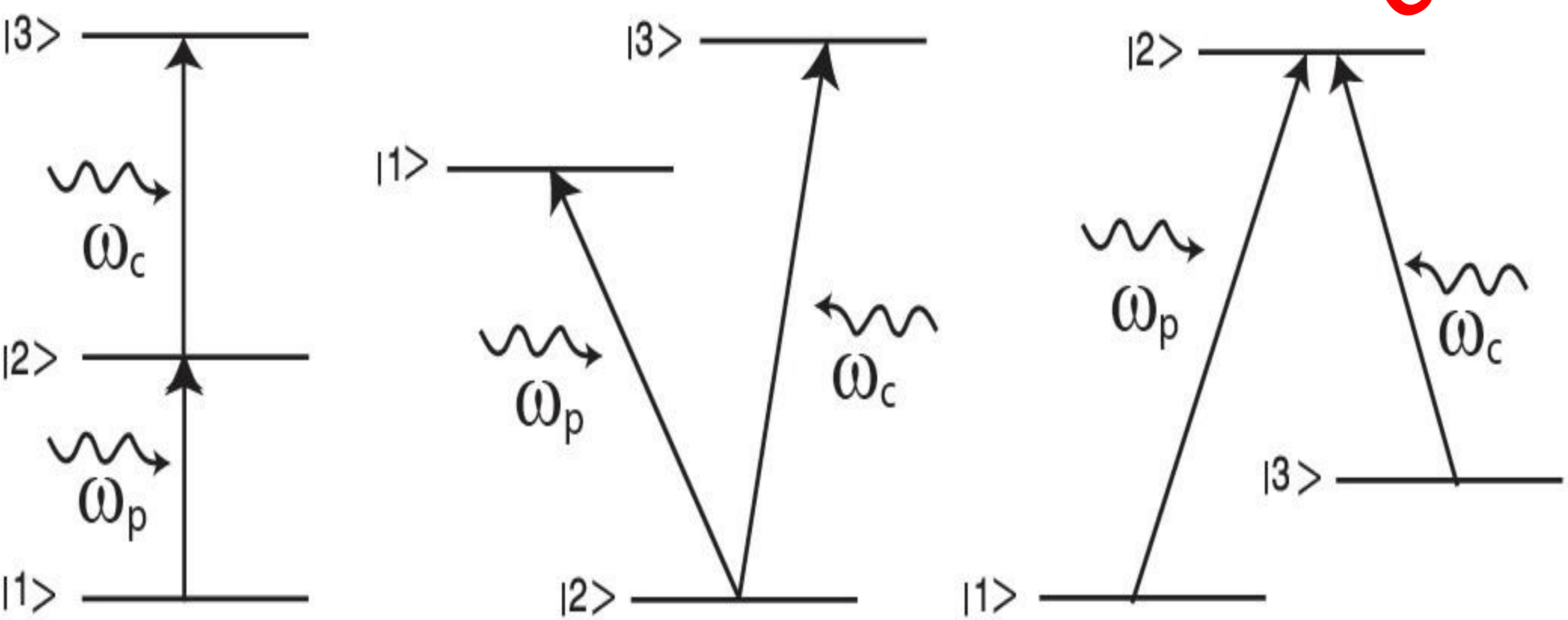
Stolen



EIT Configurations

Stolen

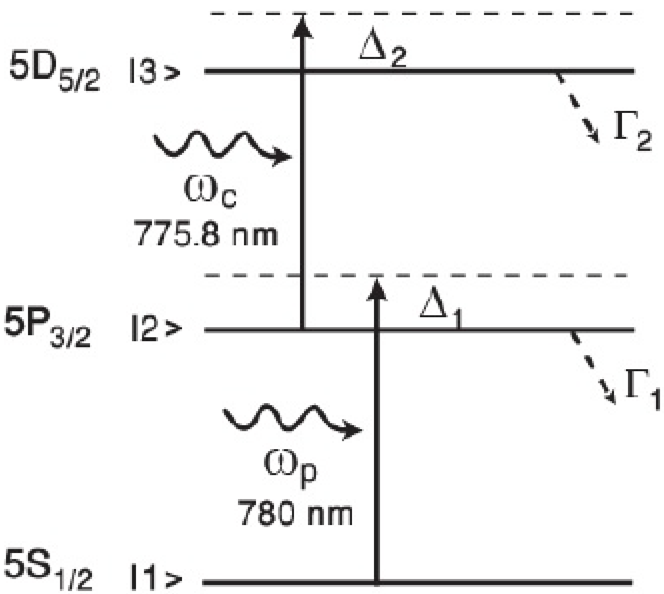
Caught



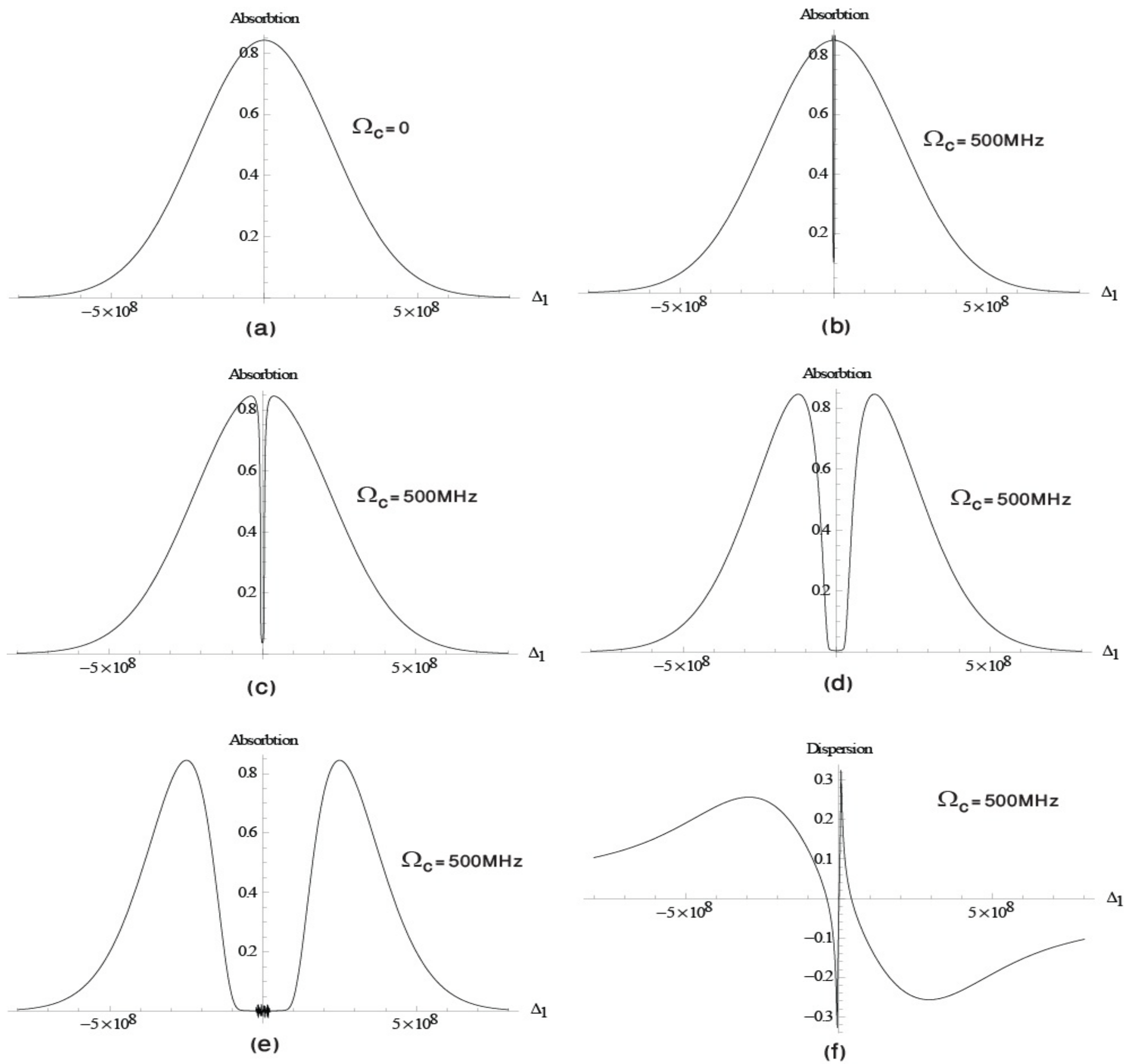
Ladder **V-type** **Lambda**

Three level Ladder type system

- Two laser beams are used to excite the electronic transitions.
- Probe beam ω_p for the transition $|1\rangle \rightarrow |2\rangle$, coupling beam ω_c for $|2\rangle \rightarrow |3\rangle$.
- $\Delta_1 = \omega_p - \omega_{21}$ probe beam detuning while $\Delta_2 = \omega_c - \omega_{32}$ is the coupling beam detuning.



Results

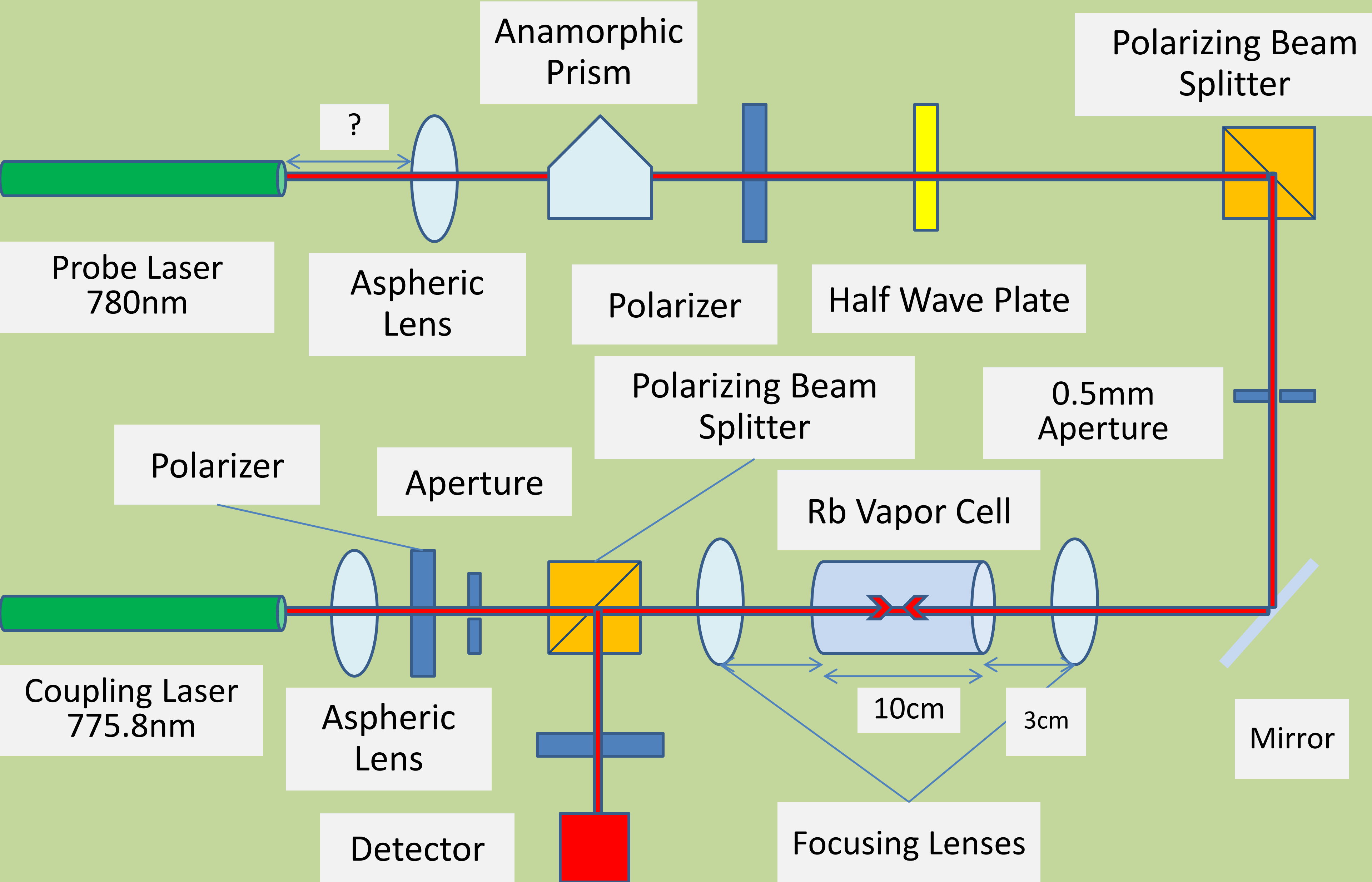

Absorbtion
0.8
0.6
0.4
0.2
$\Omega_c = 0$
-5×10^8
5×10^8
Δ_1
(a)
Absorbtion
$\Omega_c = 500MHz$
(b)
Absorbtion
$\Omega_c = 500MHz$
(c)
Absorbtion
$\Omega_c = 500MHz$
(d)
Absorbtion
$\Omega_c = 500MHz$
(e)
Dispersion
0.3
0.2
0.1
−0.1
−0.2
−0.3
$\Omega_c = 500MHz$
(f)

Time Travel

23 September 2011

Experimental Setup

Setup


Anamorphic Prism
Polarizing Beam Splitter
?
Probe Laser 780nm
Aspheric Lens
Polarizer
Half Wave Plate
Polarizing Beam Splitter
0.5mm Aperture
Polarizer
Aperture
Rb Vapor Cell
Coupling Laser 775.8nm
Aspheric Lens
10cm
3cm
Mirror
Detector
Focusing Lenses

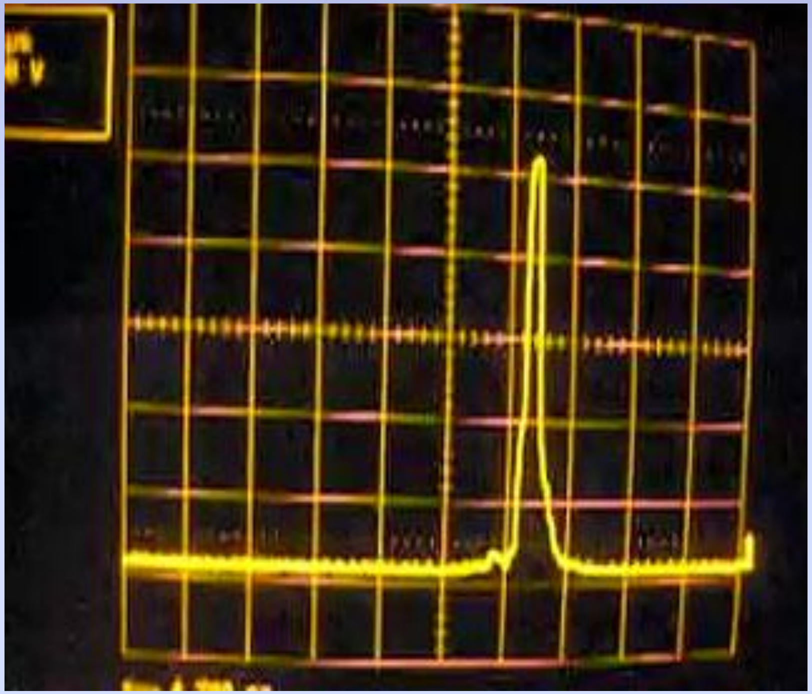
Lasers to be Used

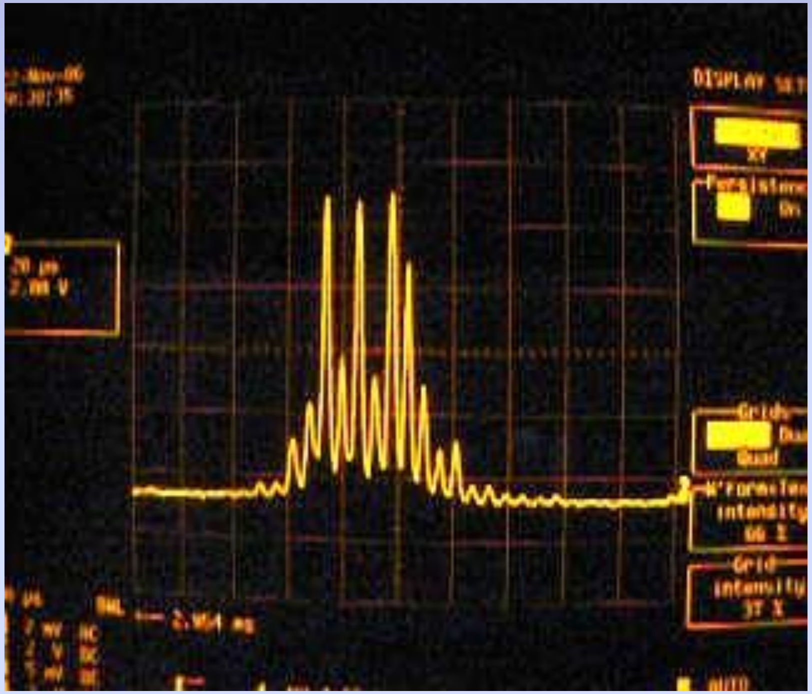
***Considerations*:-**

- Single Mode
- Narrow Linewidth (5Mhz at max)
- Widely Tunable (at least 770-790nm)
- Reasonable Frequency Stability
- Power (at least 50mW)

Single Mode

Multi-Mode





Linewidth

- ***Spectral Width***:-
  Spectral width is the wavelength interval over which the magnitude of all spectral components is equal to or greater than a specified fraction of the magnitude of the component having the maximum value.
- ***Fullwidth Half Maxima***:-
  Full width at half maximum. This is the same convention used in bandwidth, defined as the frequency range where power drops by less than half (at most −3 dB).

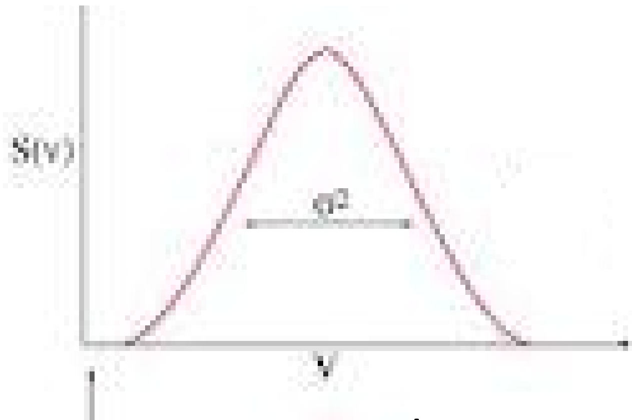
- **Linewidth or Spectral Linewidth:-**

  The spectral linewidth characterizes the width of a spectral line, such as in the electromagnetic emission spectrum of an atom,

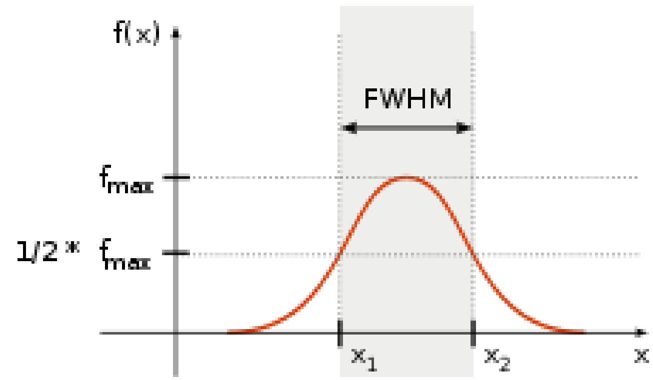
- **Bandwidth:-**

  Bandwidth is the difference between the upper and lower frequencies in a contiguous set of frequencies.

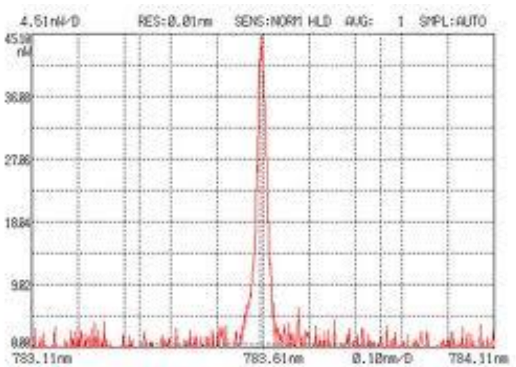
Diagrams



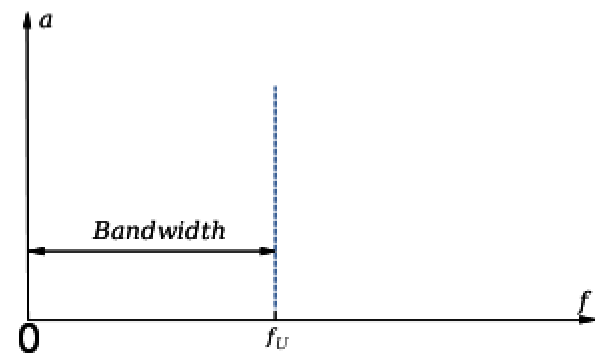
Spectral Width



Full Width Half Maxima



Linewidth



Bandwidth

Options

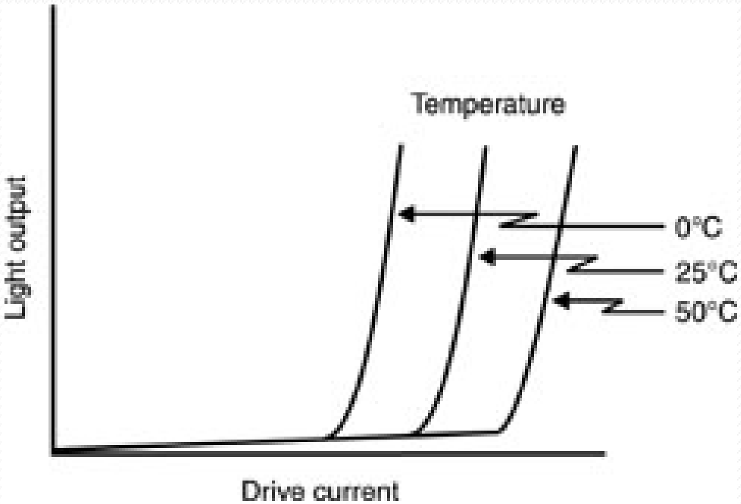
- *Distributed Feedback Diode Lasers (DFB)*
- *Distributed Bragg Reflector Diode Lasers(DBR)*
- *Extended or External Cavity Diode Lasers (ECDL) (Expensive)*

Distributed Feedback Diode Lasers

- A diffraction grating is incorporated in the semi-conductor lasing medium itself.
- Narrow Linewidths
- Not widely tunable though (6nm at best)
- Operating Wavelength set during manufacturing.
- Wavelength can be varied by strictly controlling the current and temperature parameters.

Wavelength for Power

- As temperature increases, wavelength increases but the power goes down.
- To increase the power if we increase the current, the temperature again is affected and hence so is the power and the wavelength



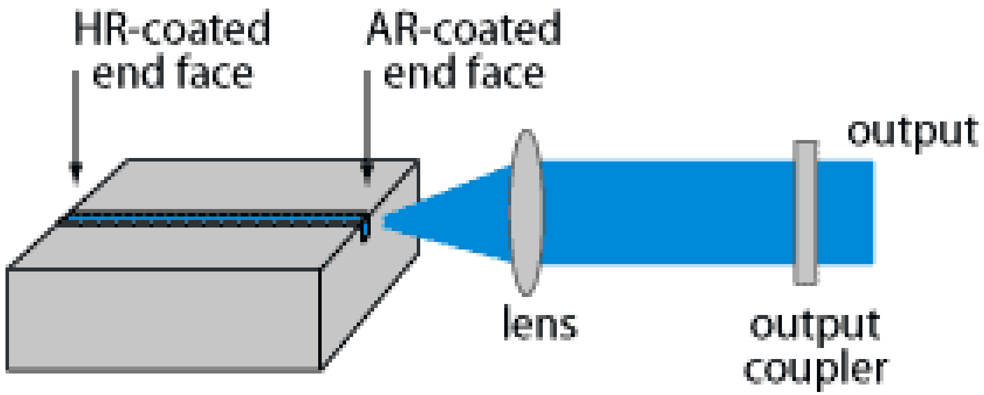
Distributed Bragg Reflector Diode Lasers

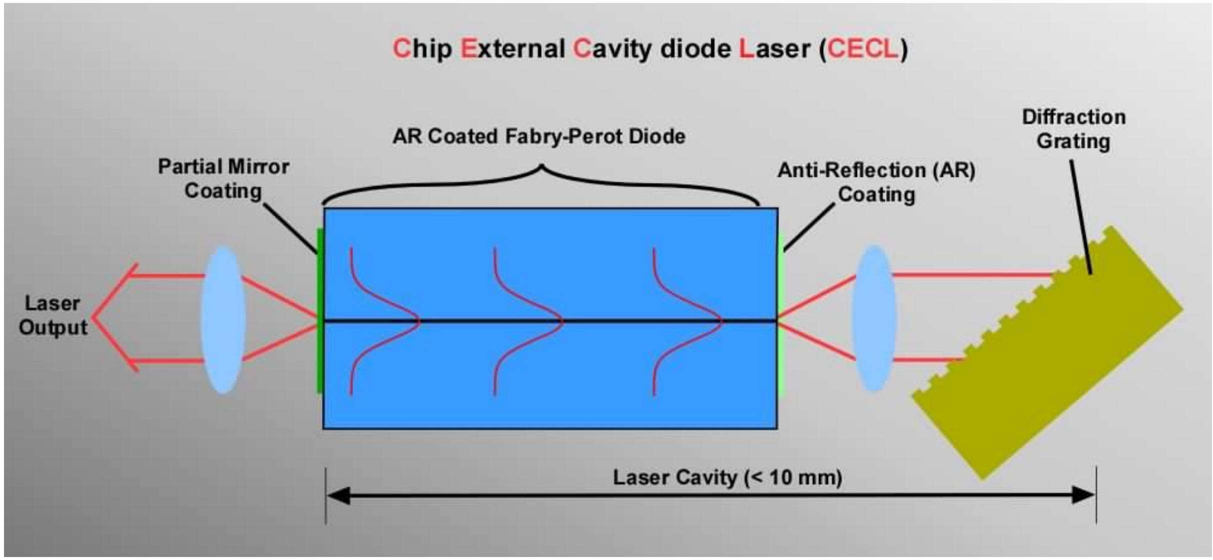
- The Diffraction Grating is outside the Lasing medium but exactly at its end.
- Acts as a filtering mirror.

External Cavity Diode Lasers

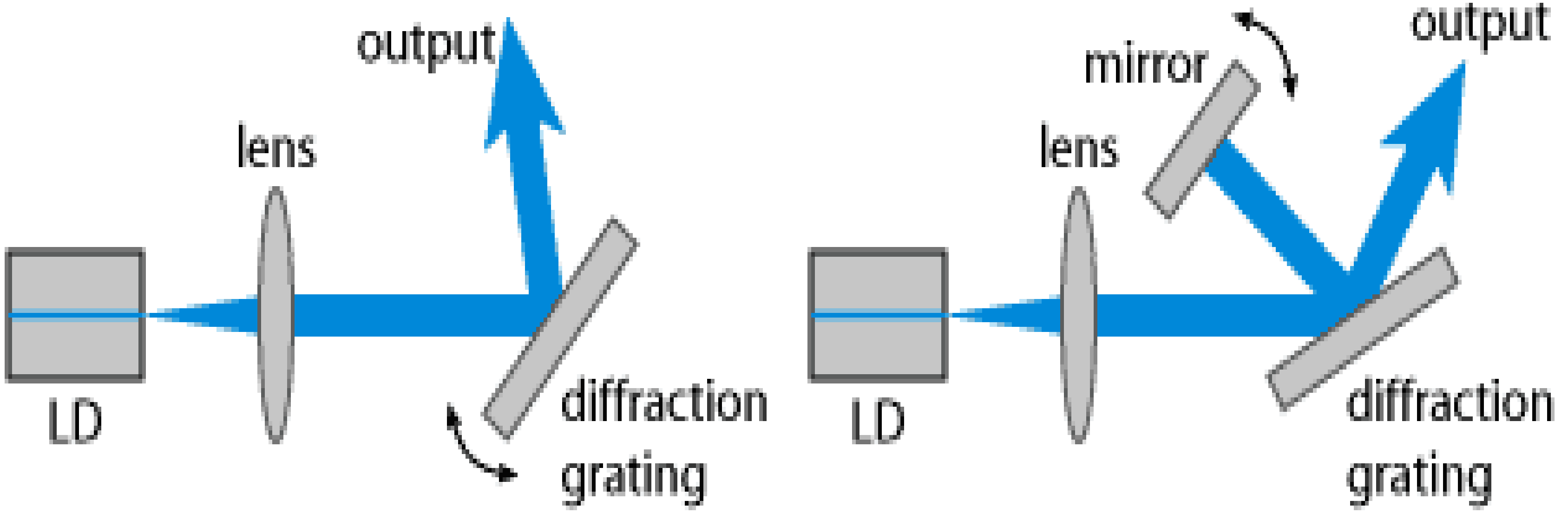
- ECDLs are complete laser systems and that is what adds up to their cost.
- The diffraction grating is outside of the lasing medium and at some distance from it.
- The wavelength is adjusted by varying the distance of the grating from the cavity using piezo-electric effect.
- So no loss of power during wavelength variation.

Construction of ECDLs





ECDL Configurations



a) Littrow configuration

b) Littman-Metcalf configuration

VARIABLES TO BE CONTROLLED

Variables

- Wavelength → Detuning
- Intensity → Rabi Frequency
- Polarization
- Beam Shape and Size
- Quantum Phase

Wavelength

- We will vary the frequency of the probe laser and take the readings of its absorption through the Rubidium Vapor Cell.
- The coupling beam doesn't need to be varied in its frequency.
- We expect to see a huge reduction in absorption when the probe beam frequency matches the 780.24nm transition in Rb (D2 line).

Intensity

- We need at least 20mW of power of the coupling laser at the Rb Vapor Cell.
- About 250uW of power from the probe laser.
- Using NDF filters we can control the intensity of the lasers.

Neutral Density Filters

- An ideal neutral density filter reduces and/or modifies the intensity of all wavelengths or colors of light equally, giving no changes in hue of color rendition.

$$d = -\log(I/I_o)$$

where Io is the incident intensity

Rabi Frequency

- Intensity depends on the laser current and not the power.
- Rabi frequency depends on the intensity and the coupling strength.

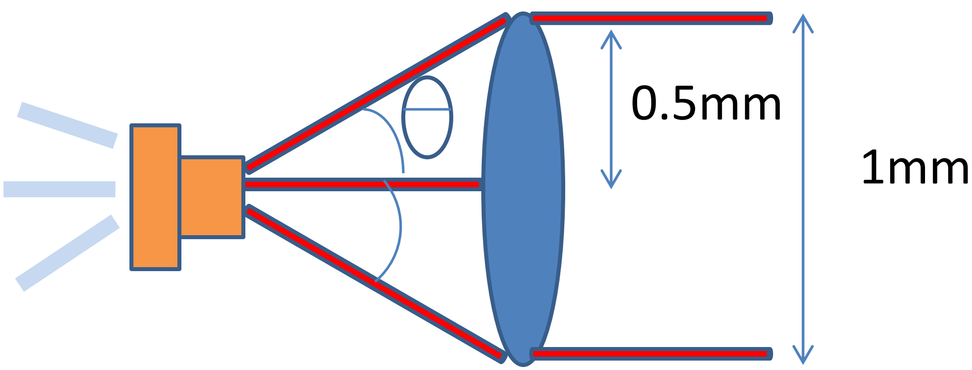
$$\Omega_c \equiv 2g_{32}E_c$$

Polarization

- The beams orthogonally polarized to each other.
- That is how then they are separated out the detector.
- Scattering can also cause polarization to change.
- That is why we have also added another polarizer before the detector to block out the scattered light from the strong coupling beam.

Beam Shape and Size

- Diode lasers give out a diverging beam.
- Aspheric Lenses are used for collimating the beam.



f=0.5/Tan θ

NA(Lens)>NA(Diode)

NA(Diode)=n Sin θ

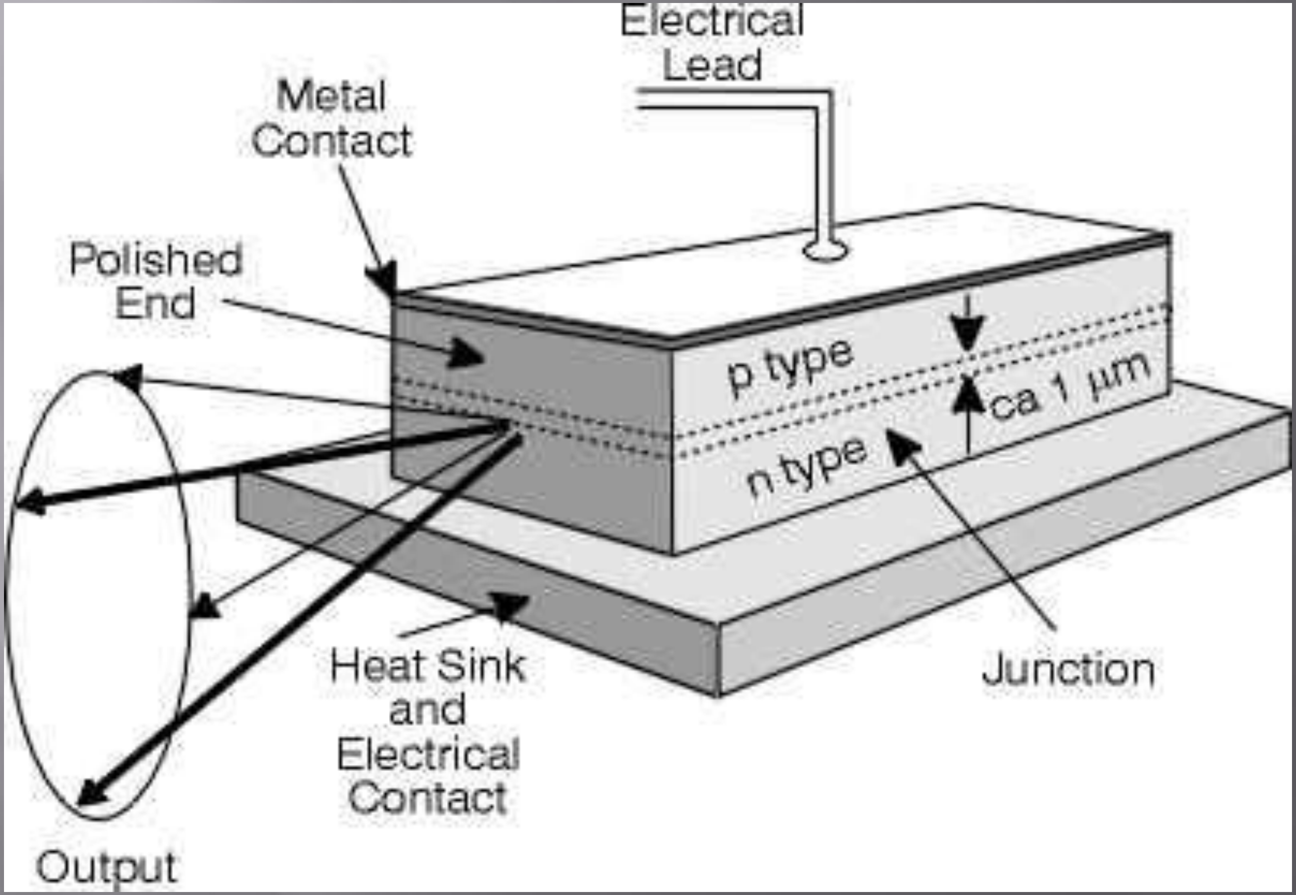
n=1 (air)

Anamorphic Prism Pairs

- They transform elliptical laser diode beams into nearly circular beams by magnifying the in one dimension.
- They can give a throughput of about 50%.

- **Problems:-**

1. They are expensive.
2. Hard to align (the beam should enter at the brewster angle).
3. The exit beam is not collinear with the laser diode.


Electrical Lead
Metal Contact
Polished End
p type
ca 1 μm
n type
Heat Sink and Electrical Contact
Junction
Output

Applications of EIT

- Fundamental and commercial applications of EIT in atomic physics and quantum optics include,
- Lasing without inversion,
- Reduction of the speed of light,
- Quantum memory,
- Optical switches,
- All optical wavelength converters for telecommunications,
- Quantum information processing.

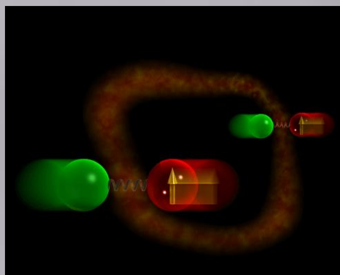
ALL OPTICAL QUANTUM NANO SWITCHES

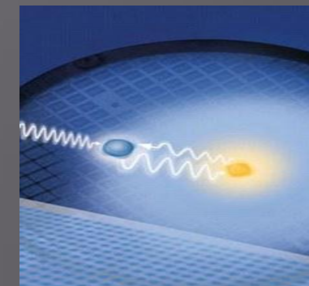
(THE WORLD'S DREAM)

- Very low loss and high efficiency.
- High Speed and complex problems processing.
- Small and Light weighted as one could wish for.

A Glance into the Future

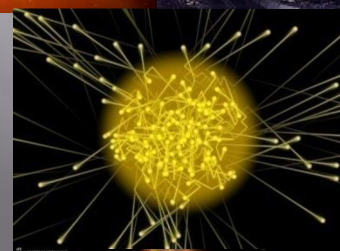
Controlled Nuclear Fusion

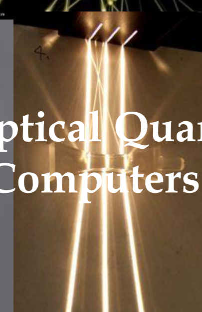




Entanglement

Bye Bye! electrons



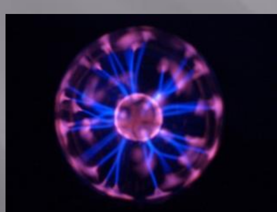


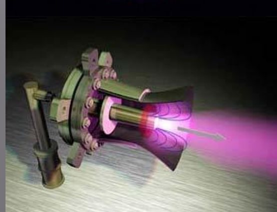
All Optical Control

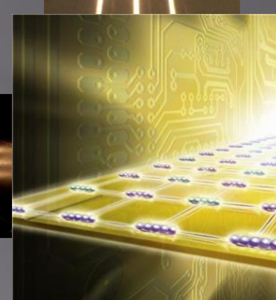
All Optical Quantum Computers

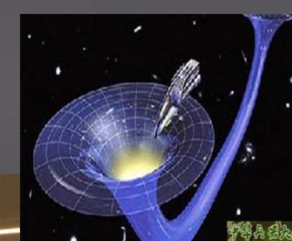
All Optical Quantum Communication

Laser-plasma converters (Laser Induced Plasma)









Plasma Motors and Engines

THANK YOU!!!