Electromagnetically induced transparency

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What is Electromagnetically Induced Transparency?

Electromagnetically Induced Transparency (EIT) is a phenomenon that can cause materials to appear totally transparent with respect towards a given frequency range. The transparency is controlled by a pumping frequency that determines the transparency frequency range.

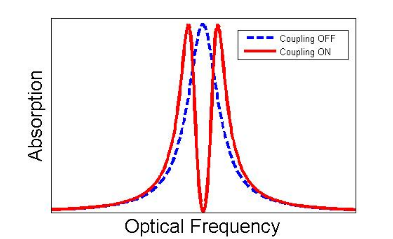

Figure: Measurement of the frequency absorption of InAs "Electromagnetically Induced Transparency"

What is Electromagnetically Induced Transparency?

Imagine trying to call someone on your cell phone, but you're in an area covered in a material that naturally can block electromagnetic waves. A way to allow the signal to pass through the material is to saturate it with a different frequency so that you can get the information out. This is EIT.

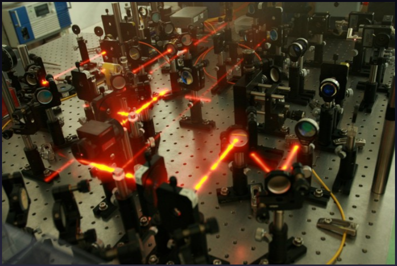

Figure: A Japanese Laboratory experiment investigating EIT and its applications in memory "Slow wave properties using EIT"

How does Electromagnetically Induced Transparency work?

EIT can be described in three different ways,

- Spring model
- LCR resonant circuit
- Quantum states

And each way of describing it has its own unique equations and consequences.

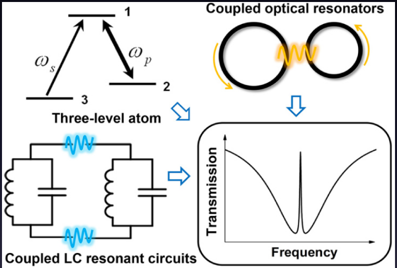

Figure: The different ways of describing EIT Zhou et al., “Phase characteristics of an electromagnetically induced transparency analogue in

How do we describe EIT with a spring model?

If we imagine the valence and inner band electrons of an atom bouncing up and down in their distinct band, we can describe it as two unique springs. These spring equations are modeled by Particle 1:

$$\frac{dx^2}{d^2t}+\gamma\frac{dx}{dt}+\omega^2x_1-\Omega^2x_2=\frac{F}{M}e^{-j\omega_s t}$$

Particle 2:

$$\frac{dx^2}{d^2t}+\gamma\frac{dx}{dt}+\omega^2x_1-\Omega^2x_2=0$$

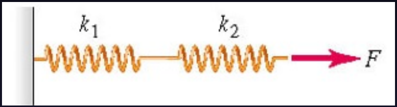

Figure: Dual spring model

These springs will transfer energy with each other with respect towards a distinct resonant frequency. When energy is added into the system with respect to that frequency neither spring will move. Because of this, neither electron (Or spring) can absorb any new

How do we describe EIT with a LCR model?

Instead we can also imagine the electron as an abstraction of resistors, capacitors and inductors. In this system, an electric wave passes through the circuit. As it does, the wave is split into two different energy storage devices depending on the frequency of the wave. If the frequency is just right, then the wave is no longer split and instead can move without any restriction. This is called resonance and is often used in filtering and in amplifier design.

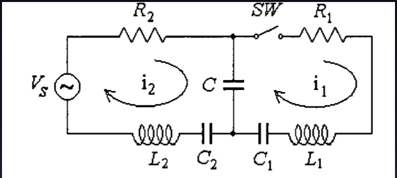

Figure: Resonant circuit description of the two electrons

In EIT, we employ this exact same thought process towards describing the electron.

How do we describe EIT with quantum states?

The electron is a quantum object, it doesn't actually exist with a distinct point unless interacting with other particles. Instead it exists in distinct states inside the atom and its interactions with other particles describe these states. Imagine state its first state being a room temperature state, |1>. The electron exists in the outer part of the atom and can sometimes interact totally independently. The next state is 'above' the current placement, also known as the conduction band |2>.

The electron can be moved around very easily away from the atom. Lastly there is the ground state, where the electron is tightly placed into the valence band |0>.

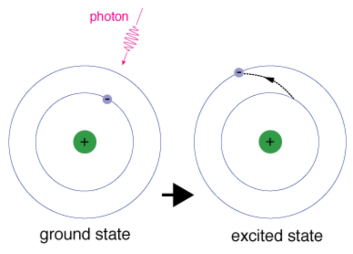

Figure: Different states of the electron inside an atom Smale, "Understanding the atom"

How do we describe EIT with quantum states?

When exposed to light, the electron will usually begin moving in response having absorbed the energy. If the electron absorbs enough energy, or has enough at a given time it will transfer to a new state. With EIT, we are intentionally switching the electron between state |0> and state |2>.

By doing this, the electron will not have enough energy, usually provided in state |1> to absorb and emit the energy.

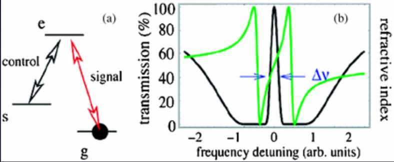

Figure: The electron moving quantum states

Why do we care about EIT?

By utilizing technologies that create slow wave propagation, and control that slow wave propagation, such as EIT, we can store the quantum states of particles in such a way towards using it for advanced forms of memory.

As well, we can use this technology for optical switching, where we can control when certain light propagates and when it transmits. This means EIT can be used for optical filtering and transmission.

Testing

- "Electromagnetically Induced Transparency". In: (). url: https://en.wikipedia.org/wiki/Electromagnetically_induced_transparency.
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