Slow light in a cold disc

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Slow Light

A pulse of light is made up of individual (phase) components, which travel with individual (phase) speeds. Imagine an army of ants all walking along in a line with two layers. The bottom layer walks with one speed and the top layer walks on top of them, moving to the front of the line faster, because they have the added speed of the bottom layer. These two layers are like two phase components of a pulse of light. If the whole line of ants is studied then it can be seen that the speed with which the line moves is not the same as the two layers but results directly from how fast the layers move. This is like the group velocity of a light pulse, which describes the speed of the envelope of the pulse, i.e. how fast all the phase speeds move altogether. When the light pulse experiences certain materials or structures, called slow light structures, the group velocity can be slowed down a lot, sometimes even stopped entirely. This is called slow light. In non-linear optics experiments, where the interaction between light and atoms is studied, an increase in the interaction time, due to slower light, means the measurements can become very sensitive. These can then be used to make optical sensors where very small changes can be noticed because of the use of slow light.

Whispering Gallery Resonators

Whispering Gallery Mode Resonators (WGMRs) are round cavities which can trap light. An optical cavity traps light by reflecting it, normally off mirrors, so that the light bounces back and forward between them. WGMRs are made of materials which, when highly polished, can confine light by total internal reflection (TIR). Since they are circular, the light bounces along the rim of the circle and can be likened to a stone skimming the seawaters surface. Every time the light bounces off the rim some of the light slips out of the cavity (an evanescent field) but is not necessary lost from it, a little bit like the skimming stone causing a little splash with each bounce. If there is nothing near the stone when it bounces then the drops from the splash will fall back into the seawater. If an object is close enough to the splash though, the water will end up on the object. In a similar way the energy of the light stays in the cavity unless an object is close enough to it, i.e. within the evanescent field. If so then the light can leak out of the cavity through the object, using it as a tunnel. Whenever TIR happens in any object an evanescent field will leak out of the it. If the WGMR is then moved close enough to an object with TIR in it, the light can leak into the WGMR, where it becomes trapped. Once trapped, the light travels around the inner rim of the cavity. If the path it takes creates a closed loop it will build up, similarly to drawing a circle on a piece of paper and continuing to retrace the same circle over and over again, making the line more intense. This is known as the resonance, or mode, of the cavity.

Figure 1: A Whispering Gallery Mode Resonator glowing from the light trapped inside it.

The thesis work presented here asks what might happen if slow light is combined with a WGMR. It is suggested that ultra-sensitive (to the frequency of light) cavities can result from the increased time the light spends in the cavity. This area is not well researched and so the thesis focuses on developing an experimental setup where it is possible to get light into the WGMR and trap it there. Since light is trapped very effectively in WGMRs it is not easy to get the light into it since, as described above, the mechanism for transferring the light in is the same as transferring it out. The main work of the thesis is therefore to optimise the light transfer into the cavity such as choosing the correct beam focal size and making sure the beam is level and in line with the cavity.

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