‘Slow’- and ‘fast’-light in a single ring-resonator circuit: theory, experimental observations, and sensing applications

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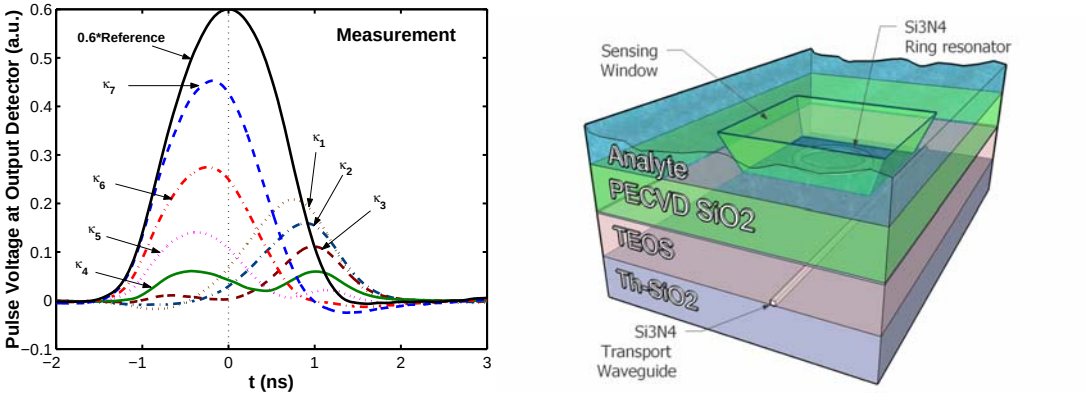
Abstract

Transfer matrix method (TMM) was used to study the phenomena of ‘slow’- and ‘fast’-light in a single two-port ring-resonator (TPRR) circuit theoretically. Their classifications into ‘slow’- and ‘fast’-light with negative and positive group velocity (v_g), where ‘slow’ means $|v_g|<c$ and ‘fast’ means $|v_g|>c$, will be introduced. The role of such phenomena in controlling light-matter interaction and pulse delay/’advancement’ will be discussed.

Direct experimental observations on pulse temporal behaviors in the regimes of ‘slow’- and ‘fast’-light with negative and positive v_g will be demonstrated, showing large and small pulse ‘advancement’ and delay, respectively. Pulse splitting phenomenon as a transition from a highly delayed to a highly ‘advanced’ pulse and vice versa, will also be experimentally demonstrated. Theoretical simulations on the pulse delay and ‘advancement’ based on the TMM and Fourier transform, which show a good qualitative agreement to the experimental results, will also be presented.

The exploitation of ‘slow’-light, either with positive or negative v_g for enhancing light-matter interaction will be discussed through evaluating their effects to the performance of integrated-optical refractometric sensor. It will be shown that when the light is ‘slow’, either with negative or positive v_g, there is enhancement of the sensor sensitivity. An integrated-optical sensor which exploits such properties and exhibits sensitivity of one order better than the present day state-of-the-art commercial Mach-Zehnder interferometer refractometric sensor, will be presented.



(a) (b)

Figure (a). Direct experimental measured pulse delay, ‘advancement’, and splitting in a TPRR circuit, demonstrating the pulse temporal behaviors in ‘slow’-light with positive and negative v_g. (b). Part of an integrated-optical sensing platform exploiting the ‘slow’-light behavior in a TPRR circuit.