Nonlinear microcavity under coherent control
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Context
The high magnification factor of photonic crystal microcavities make them useful for all-optical on-chip devices applied to signal processing. In these cavities, the electromagnetic field strengthening, which leads to an enhancement of the non-linearities, induces non-linear losses and a frequency drift of the cavity resonance. Thus, during the excitation, a mismatch between the resonance and the pulse frequency appears and induces a ringing phenomenon which limits the energy coupled inside the cavity. In order to overcome this limitation, we present here the dynamic behaviour of non-linear microcavity under a coherent excitation. Similarly to the coherent control of molecular and atomic systems, it uses an excitation pulse with a controlled phase shape. Numerical simulations have been conducted on a semiconductor GaAs microcavity operated around 1550 nm with picosecond pulse duration.

Nonlinear semiconductro microcavities
- Source term → nonlinear polarization $P_{NL}(t)$
- Refractive index variation $\Delta n$
- Optical Kerr effect
- Free carrier refraction (FCR)
- Two-photon absorption (TPA)
- Nonlinear losses $\Delta n$
- Carrier density: $N(t) = \int_{0}^{t} \frac{3}{\hbar \omega_0} F(t')dt'$
- Free carrier absorption (FCA)

Applications in optical signal processing

Coherent excitation of a nonlinear GaAs microcavity
Use of a dispersive medium to chirp the input pulse
- Second order dispersion: $\phi^2 = \frac{d^2\phi}{d\omega^2}$

Chirped pulse properties
- Instantaneous frequency: $\omega(t) = \frac{1}{\phi^2} + \delta \omega + \omega_{0\text{Fre}}$
- Pulse duration: $T_p = \frac{1}{\sqrt{2\phi^2}}$

Maximizing the stored energy
The stored energy is defined as: $E_{\text{stored}} = \frac{1}{2} \int u^2(t)dt$, where $T_{\text{R}}$ is the round-trip time.

Simulation results:
- $\phi^2 = 15.37 \text{ fs}^2$
- $\delta \omega = 6.11 \text{ fs}^{-1}$
- $T_p = 2 \tau$

Conclusions, future work
We have shown that a phase shaping of the pulses allows to control the dynamics of a nonlinear microcavity. In our case, this method is used to maximize the stored energy, but it can be employed for other applications – for instance, to control the dynamics of a set of coupled microcavities. The more important point is that the dynamics is controlled by the phase relation carried by the excitation beam. The next step is to demonstrate experimentally the efficiency of this method on a GaAs microcavity, in a picosecond regime.