Phonon storage of optical pulses in silicon phoXonic chips

Jean-Charles Beugnot[1], Vincent Laude[1], Sarah Benchabanne[1]
Yan Pennec[2], Bahram Djafari-Rouhani[2]
Nikos Papanikolaou[3], Alejandro Martinez[4]

[1] FEMTO-ST Institute, Univ. de Franche Comté, CNRS, Besançon, France
[2] IEMN, Univ. de Lille 1, CNRS, Villeneuve d'Ascq, France
[3] Inst. of Microelectronics, NCSR, Athens, Greece
[4] Nanophot. Technol. Center, Univ. Politécnica de Valencia, Valencia, Spain

jean-charles.beugnot@femto-st.fr

Motivation

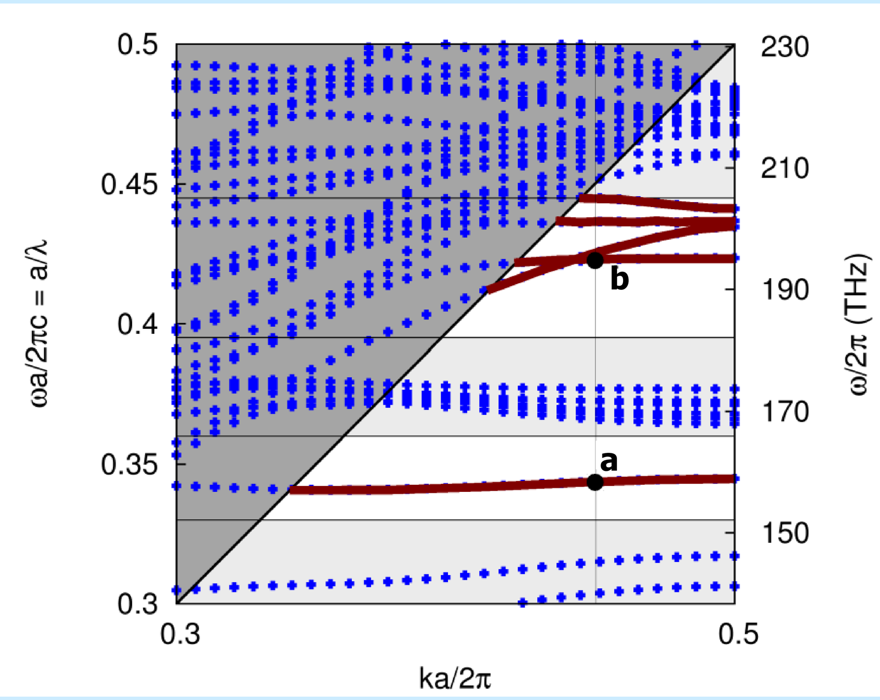
- TAILPHOX : TAILoring photon-phonon interaction in silicon PHOXonic (X=t,n) crystals
- The **tight confinement of light and sound** in such a small region, as well as their **slow group velocities** will enhance strongly the opto-acoustic interaction.

Hole diameter, a = 560 nm
Pitch = 651 nm
Thickness of the slab = 390 nm

- Develop **novel high-performance structures** and devices based on **phononic and photonic crystals**.
- **Nanosecond delays** could be realized in distances on the order of millimetres by converting optical data pulses into long-lived acoustic excitation.

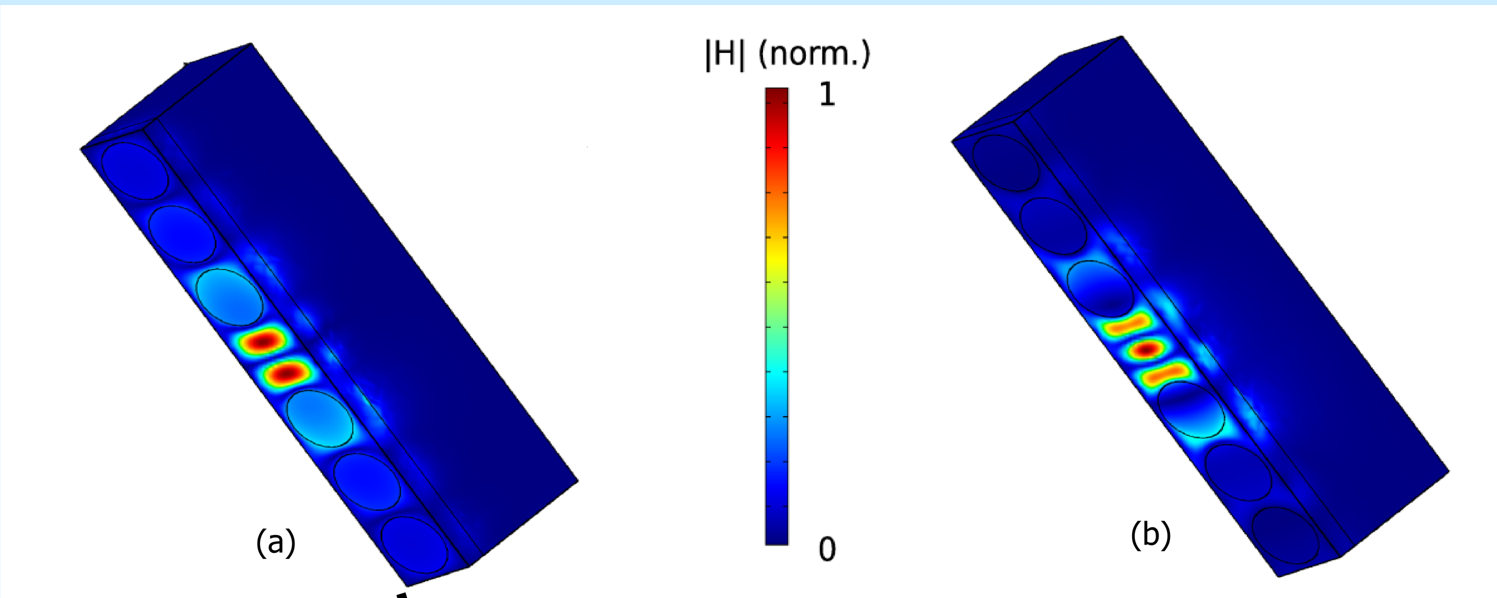
Photonic waveguide

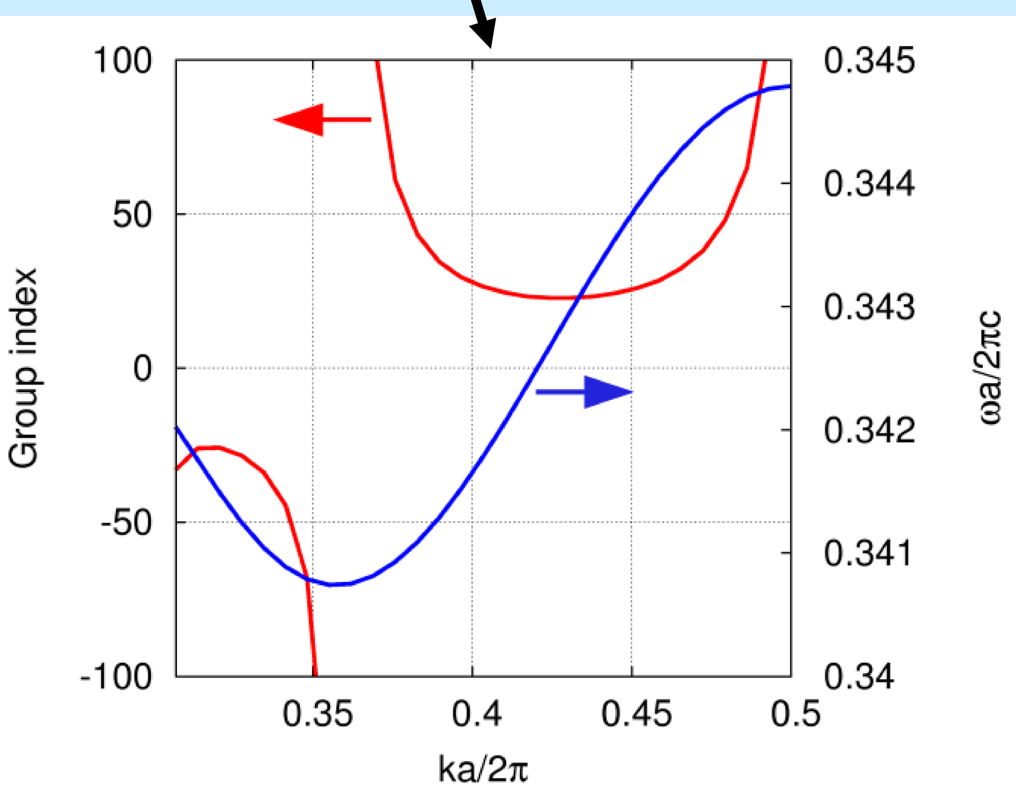
➔ **Photonic** band structure of the defect-based phoxonic crystal wavelength for even modes.



- Photonic and phononic calculation is obtained by using Finite Element Method (FEM).
- The light cone appears as the dark gray region and the band gaps for guided Bloch waves appear in white.
- Around the reduced frequency 0.35, only one additional branch appears with a very flat dispersion.

➔ Modulus of the magnetic field vector H for $k_x a/2\pi$ = 0.45



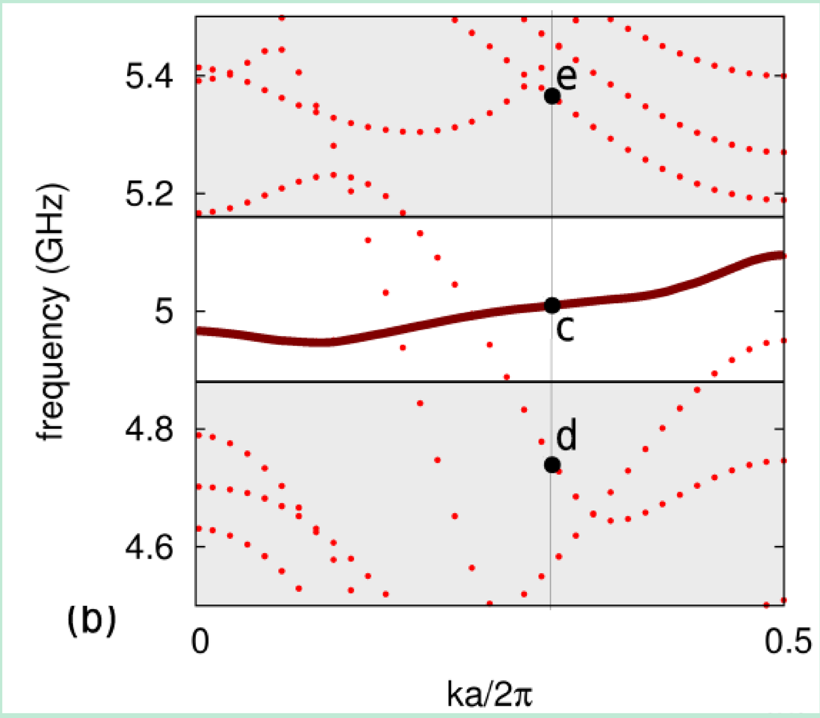


Group index and frequency reduced as a function of reduced wave vector for the guided ***phononic*** *mode*

- Both modes (a,b) are laterally guided by the photonic band gap effect
- The branch supporting mode (a) is interesting since the waveguide is monomode for even-polarized wave
- For optical wavelength equal to 1.55 µm, → n_g = 25

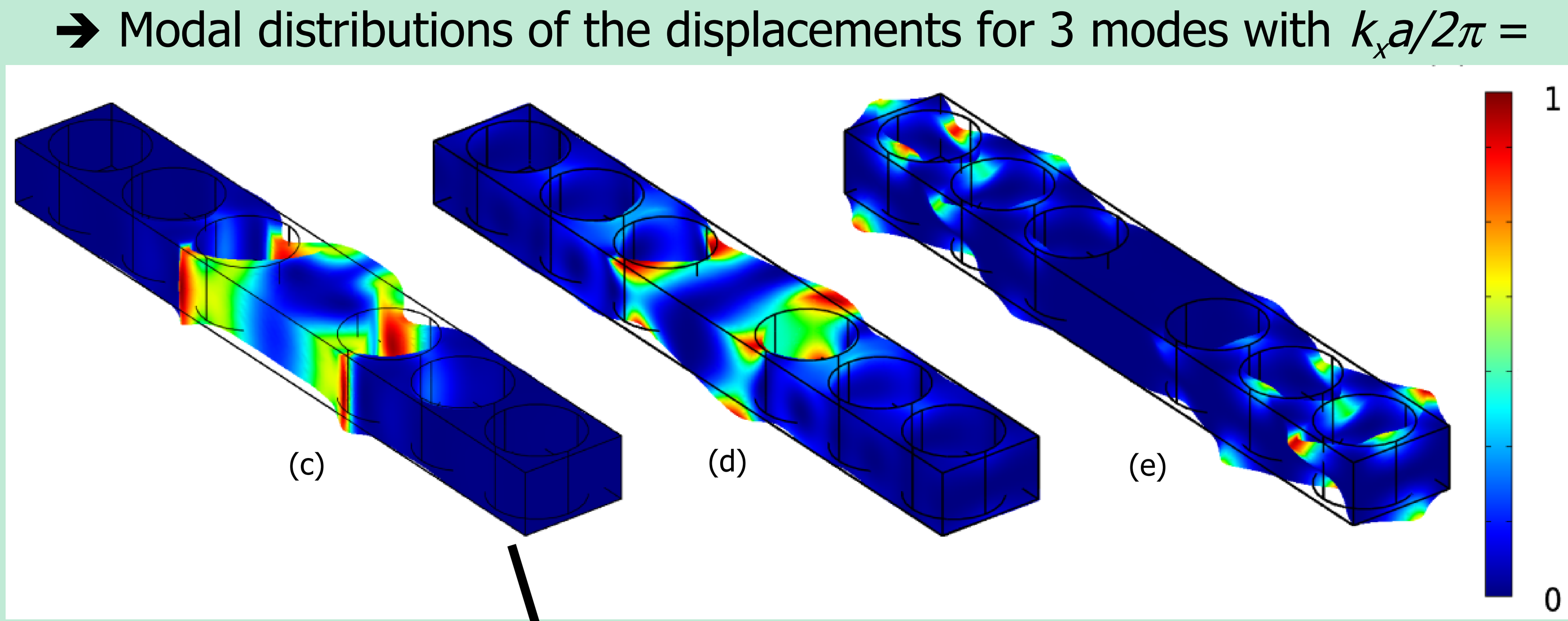
Phononic waveguide

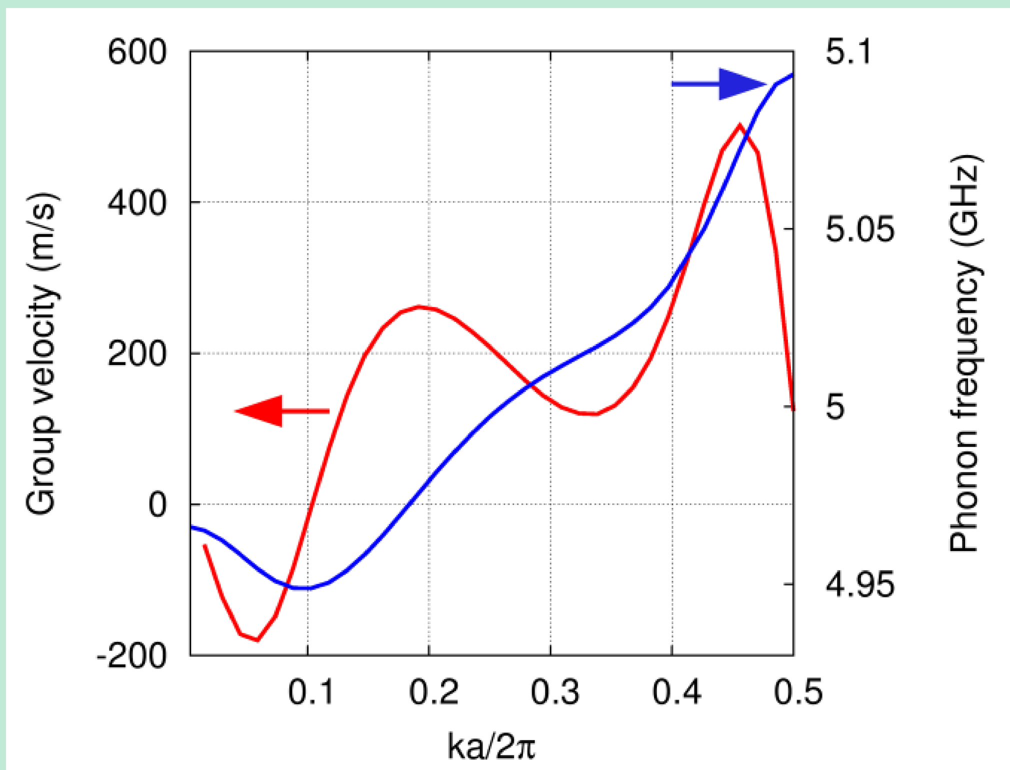
➔ **Phononic** band structure of a defect-based phoxonic crystal waveguide around 5 GHz.



- The complete phononic band gap appears in white
- One acoustic mode (continuous line) with flat dispersion, appear at 5 GHz for all axial wavevectors.
- Phononic and photonic Bloch modes are computed according to the super-cell technique.

➔ Modal distributions of the displacements for 3 modes with $k_x a/2\pi$ =





Group index and frequency reduced as a function of reduced wave vector for the guided ***photonic*** *mode*

- Bloch modes (d) is mostly guided by the core with some leakage to the side
- Bloch modes (c) is laterally guided by the phononic band gap effect for all wavevector
- For elastic frequency equal to 5 GHz, → Vg = 180m/s

➔ We predict simultaneously **slow light** (c/25) and **slow sound** (v/30) **in silicon phoxonic waveguide**.

Conclusion

The long term vision of the TAILPHOX project would permit the realization of **high performance optical devices** and applications by a phoXonic design that optimizes **the influence of acoustic waves on the optical functionality**.

- A **simultaneously phononic and photonic band gap** in silicon waveguide.
- Joint confinement of **light** and **elastic** waves with **low group velocities** is obtained.
- **New direction for the development of photonic devices** with ICT (Information and Communications Technologies) applications like **optical storage** or **phoxonic sensor**.

Acknowledgment : Future and Emerging Technologies (FET) Program within the 7th Framework Program for Research of the European Commission N° 233883.