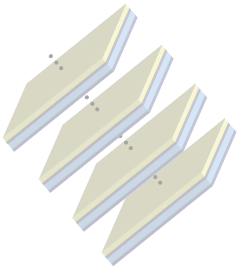
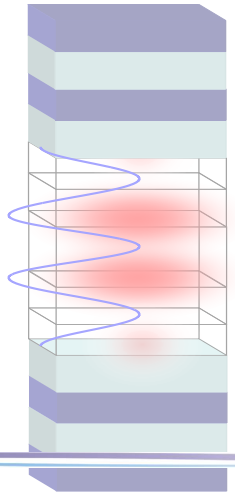
Phonon Engineering:
teaching acoustic phonons new tricks!



Daniel LANZILLOTTI-KIMURA

Laboratoire de Photonique et de Nanostructures, CNRS



LABORATOIRE DE PHOTONIQUE ET DE NANOSTRUCTURES

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Phonon Engineering:
teaching acoustic phonons new tricks!

Daniel LANZILLOTTI-KIMURA

Laboratoire de Photonique et de Nanostructures, CNRS

Xiang Zhang, Berkeley
Kevin O'Brien, Berkeley
Jun Suk Rho, Berkeley
Haim Suchowski, Berkeley
Alejandro Fainstein, Bariloche
Bernard Jusserand, Paris
Bernard Perrin, Paris

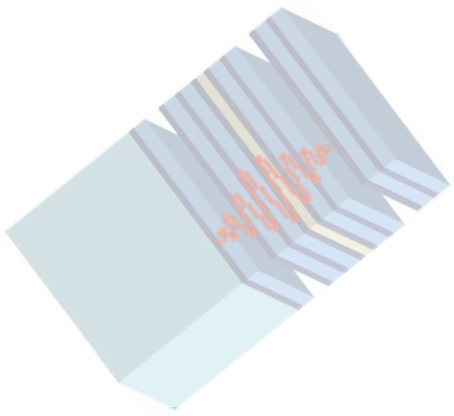
Pascale Senellart, Marcoussis
Ivan Favero, Paris
Loic Lanco, Marcoussis
Aristide Lemaitre, Marcoussis
Isabelle Sagnes, Marcoussis
Carme Gomez-Carbonell, Marcoussis

Nanophononics: playing with sound at sub-THz frequencies and nm wavelengths

What is it about?

Control the generation and detection of ultra high-frequency acoustic phonons using optical methods

Manipulate and control hypersound at the nm scale



Why?

Use of hypersonic vibrations to control sound, light and charge in nanometric scales and at ultra high frequencies.

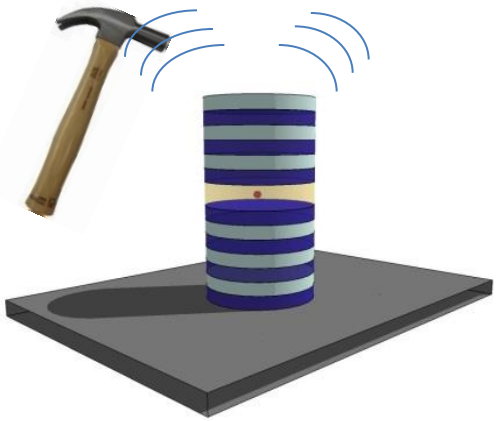
How?

1. Using **acoustic devices** to control the sub-THz vibrations
2. Using **photonic/phononic systems** to tailor light-sound interactions

Nanophononics:
engineering of acoustic phonons at GHz-THz frequencies

Acoustic phonons interact virtually
with any other excitation

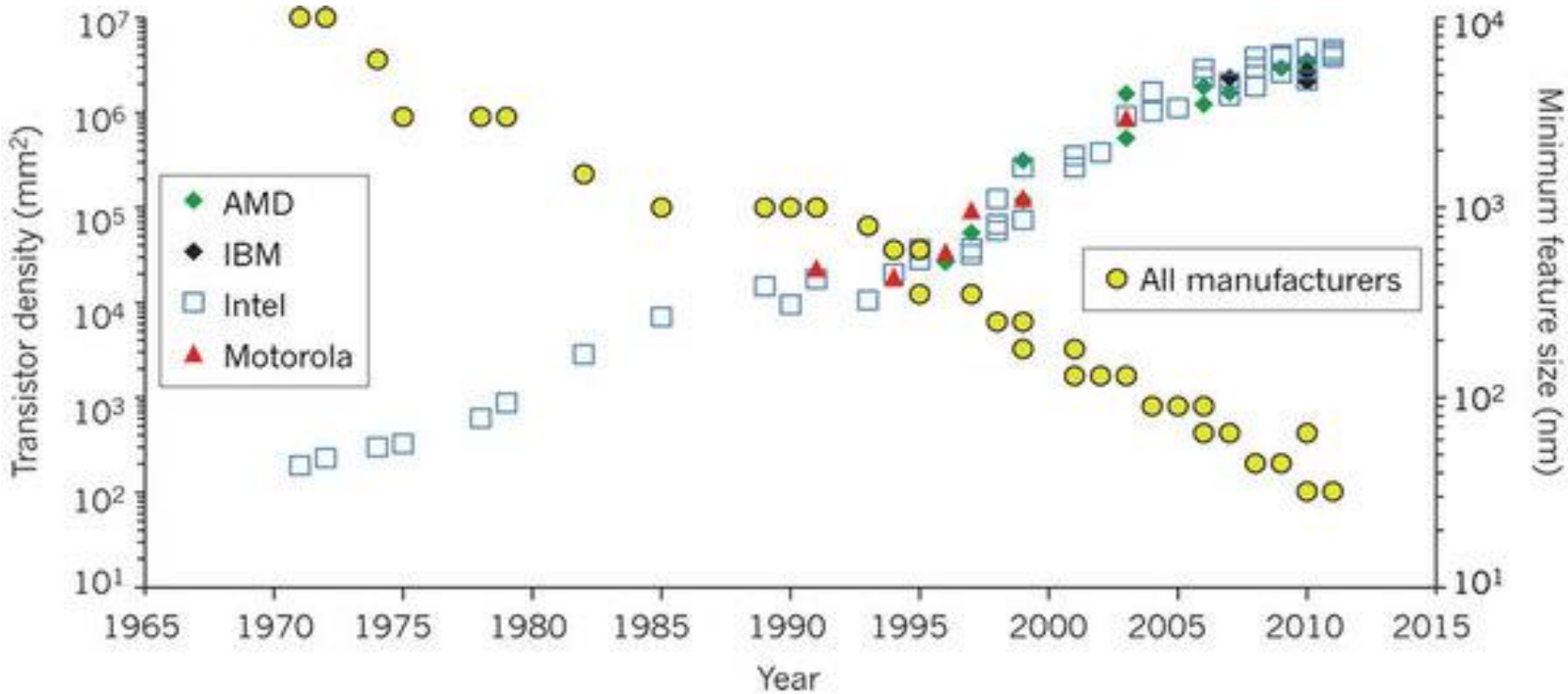
Usually seen as harmful,
we can engineer and use them
to control light and charge



Acoustic phonons modulate:

- Physical shape
- Electronic properties
- Optical properties
- Magnetic properties
- etc…

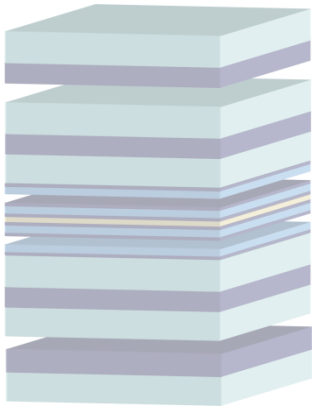
Nanophononics: playing with sound at sub-THz frequencies and nm wavelengths



Why?

1. Thermal transport is the bottleneck in nanoelectronics
2. New nanoscopies, saser
3. Novel platform for optomechanics applications including quantum information
4. It can be a lot of fun!!!

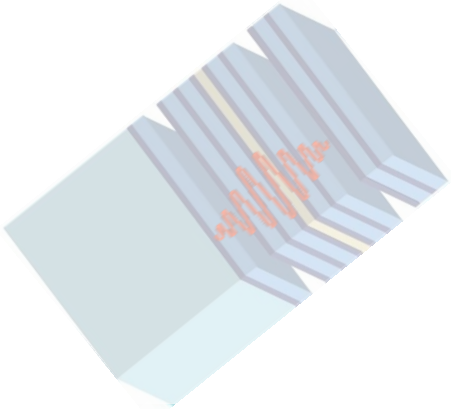
Outline



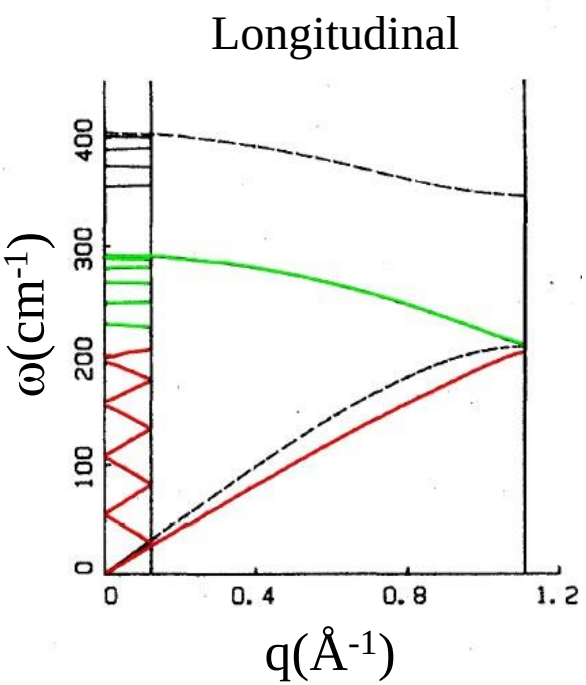
A. Acoustic phonon devices
Phonon mirrors, cavities, and other structures

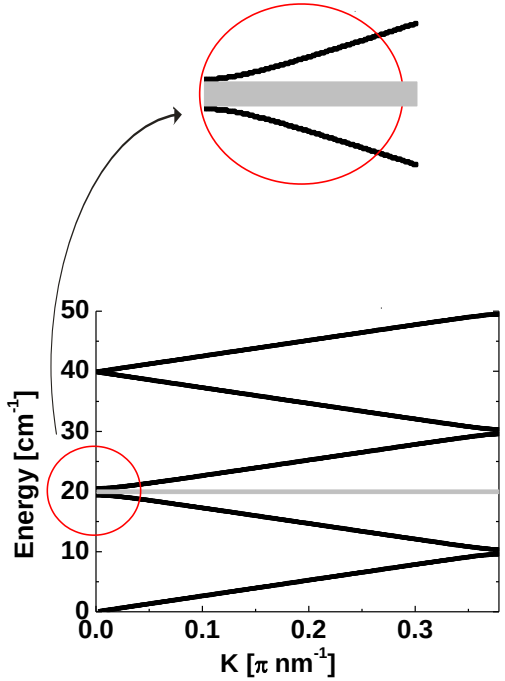
B. Magic resonators for light and hypersound
Cavities, phonon dynamics, future perspectives

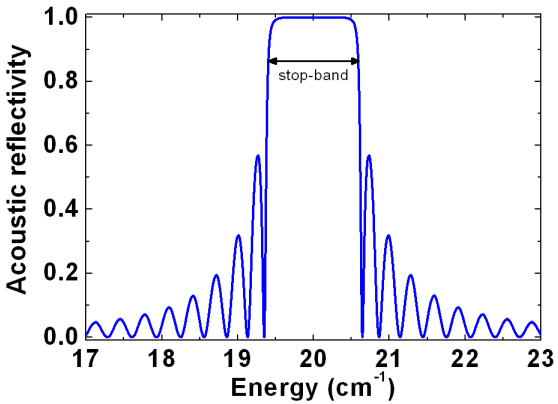
C. Ultrafast acousto-plasmonics
Phonons in metallic bars, crossed bars, complex structures

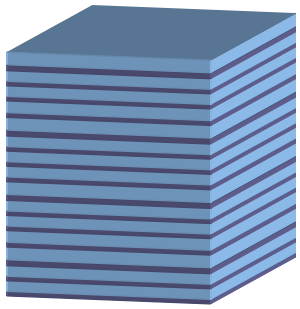


Periodic multilayers act as **phonon** reflectors



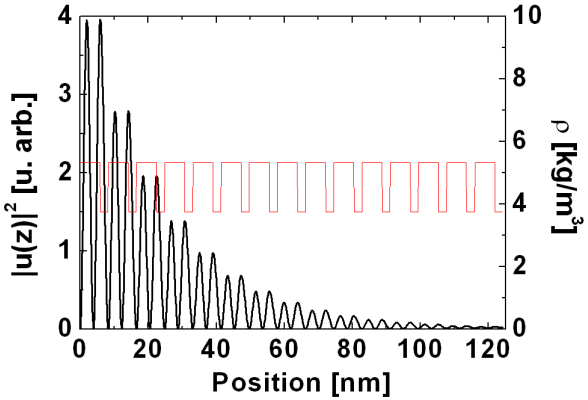






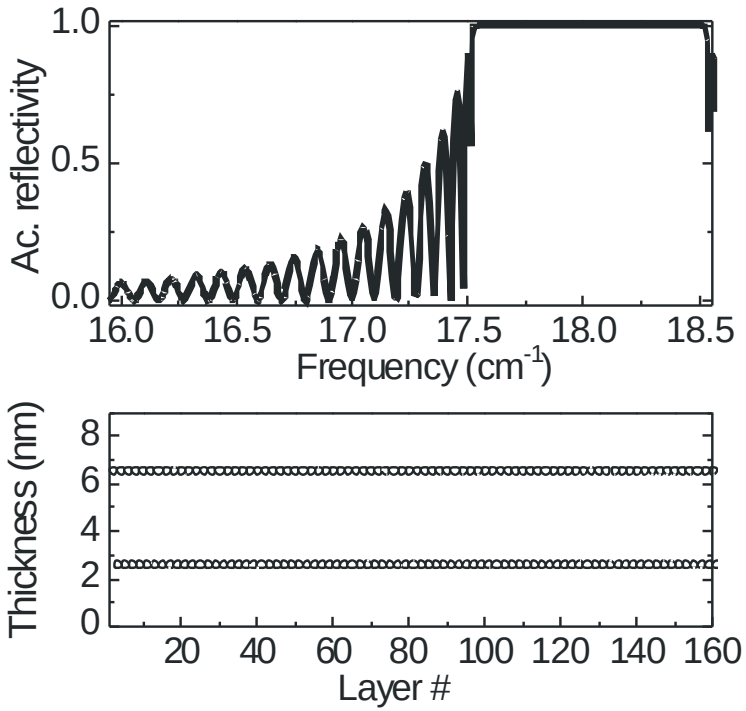
Period ~ 10 nm

Frequencies ~ GHz – THz range



The reflectivity is optimized using multivariable optimization routines

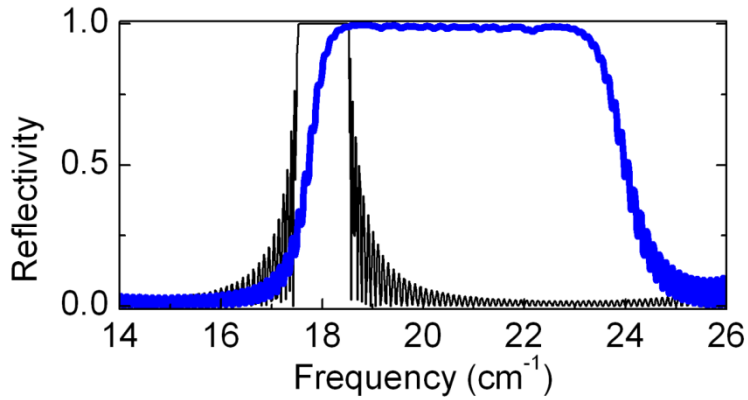
Periodic superlattice phononic reflector



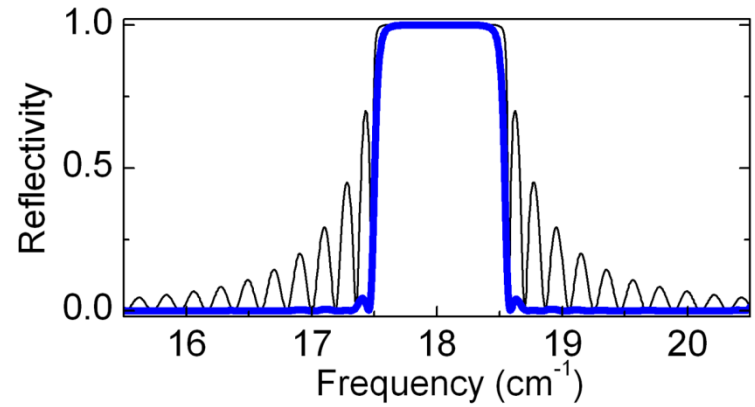
Appl. Phys. Lett. **88**, 083113 (2006)

Aperiodic stacks can have tailored responses to manipulate hypersound

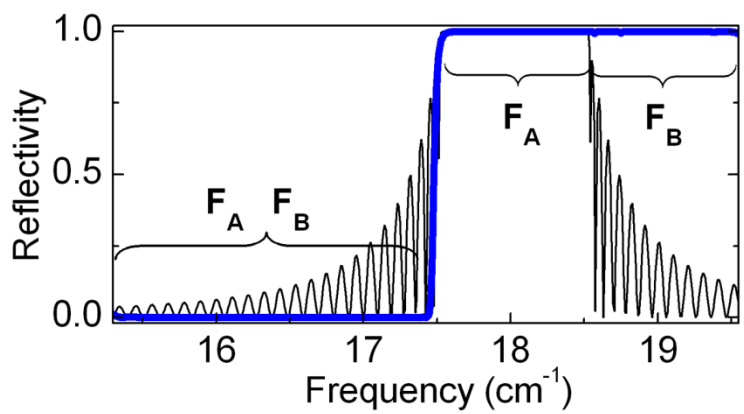
Broadband mirror



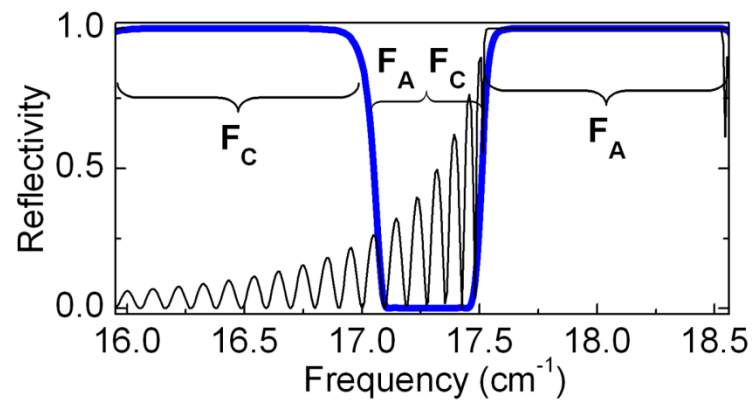
Notch filter



Edge filter



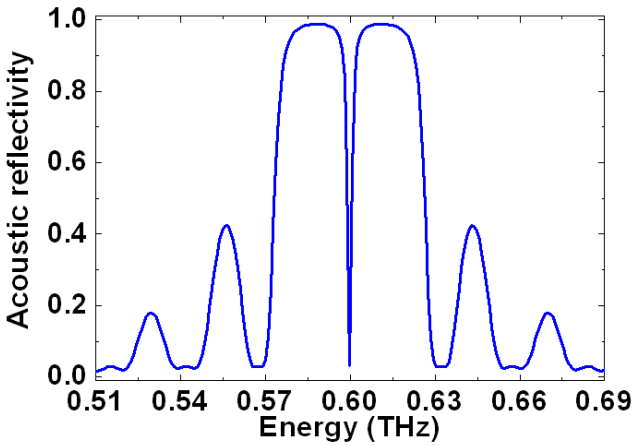
Color filter

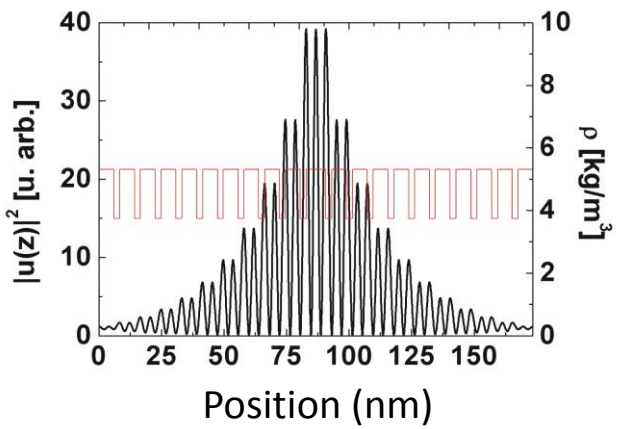


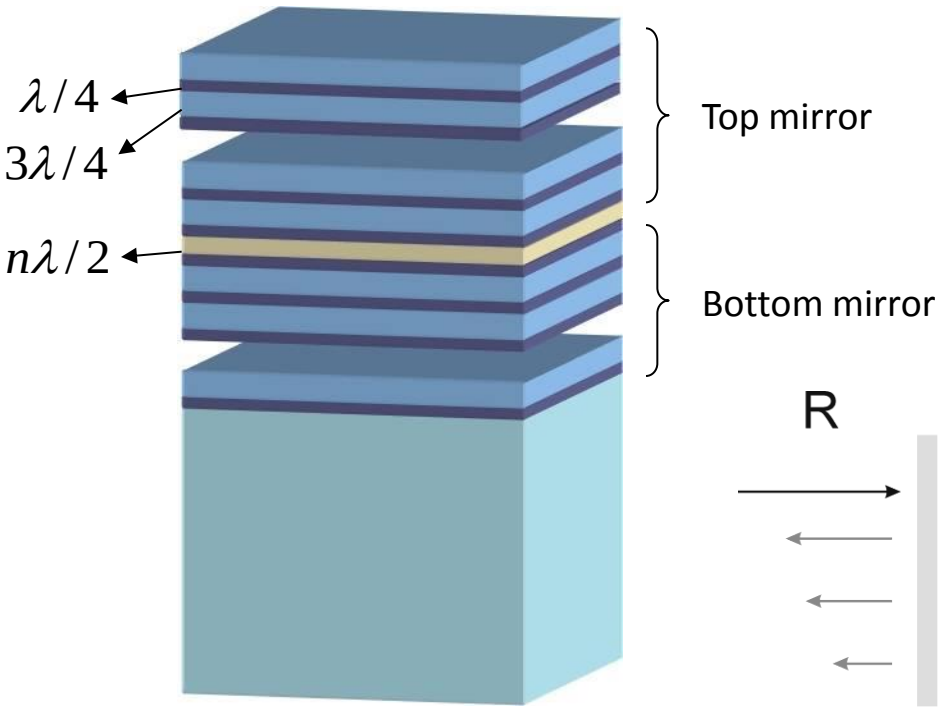
Phys. Rev. B **76**, 174301 (2007)

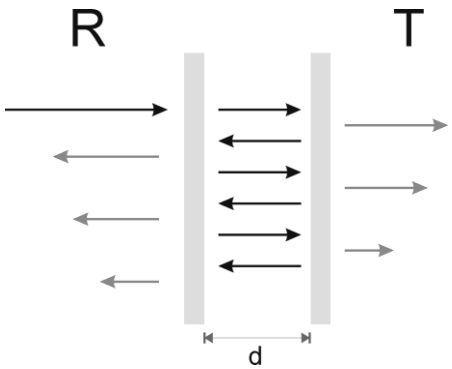
Appl. Phys. Lett. **96**, 053101 (2010)

Two phononic mirrors enclosing a spacer confine and "amplify" **acoustic** fields







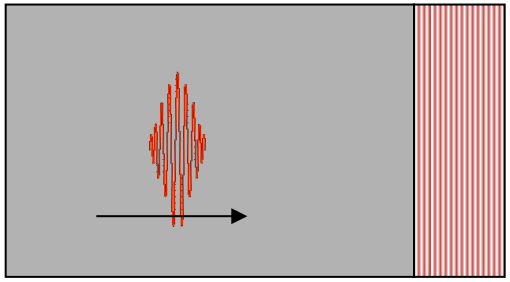


Superlattice → Phonon mirror

periods: reflectivity → Q factor

Similar to a Fabry-Perot interferometer

Two phononic mirrors enclosing a spacer confine and "amplify" **acoustic** fields



GaAs substrate | Phonon mirror | Phonon cavity