Photoacoustics metrology: Detection of grating underneath opaque metal and dielectric multilayers

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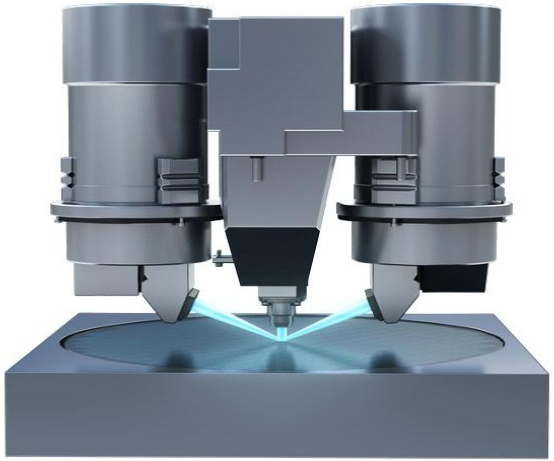
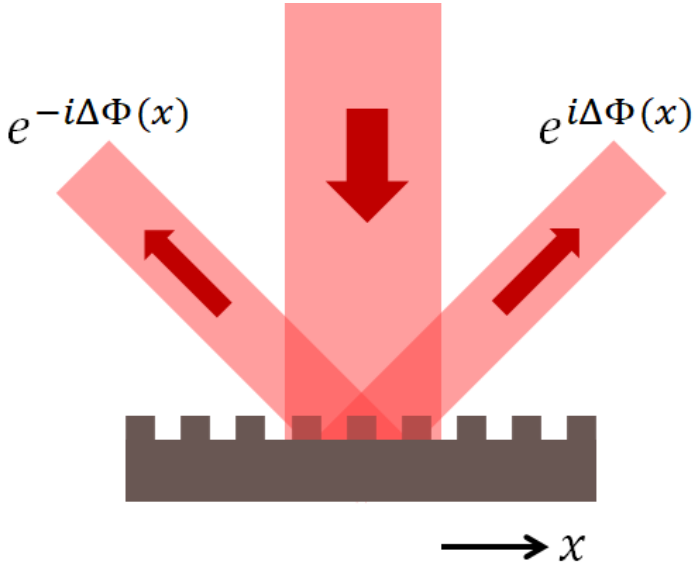
04 Nov 2019 |Amsterdam

Motivation



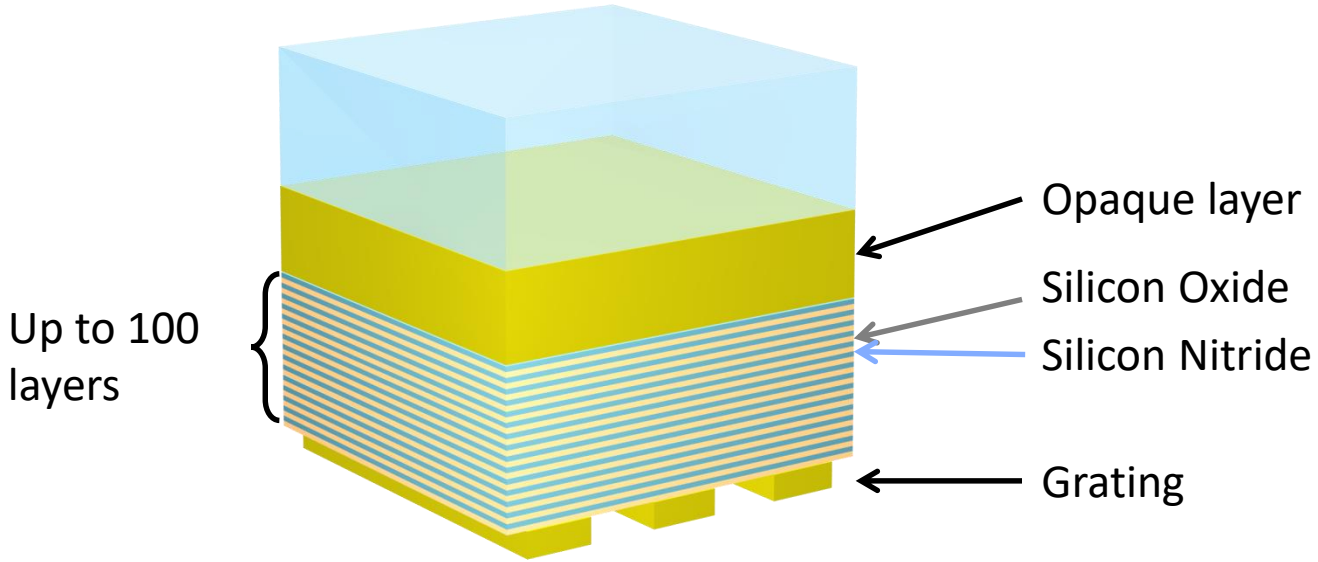
Gratings are required to position
Si wafers accurately (< 1 nm)



Grating displacement changes
Optical phase of diffracted beams

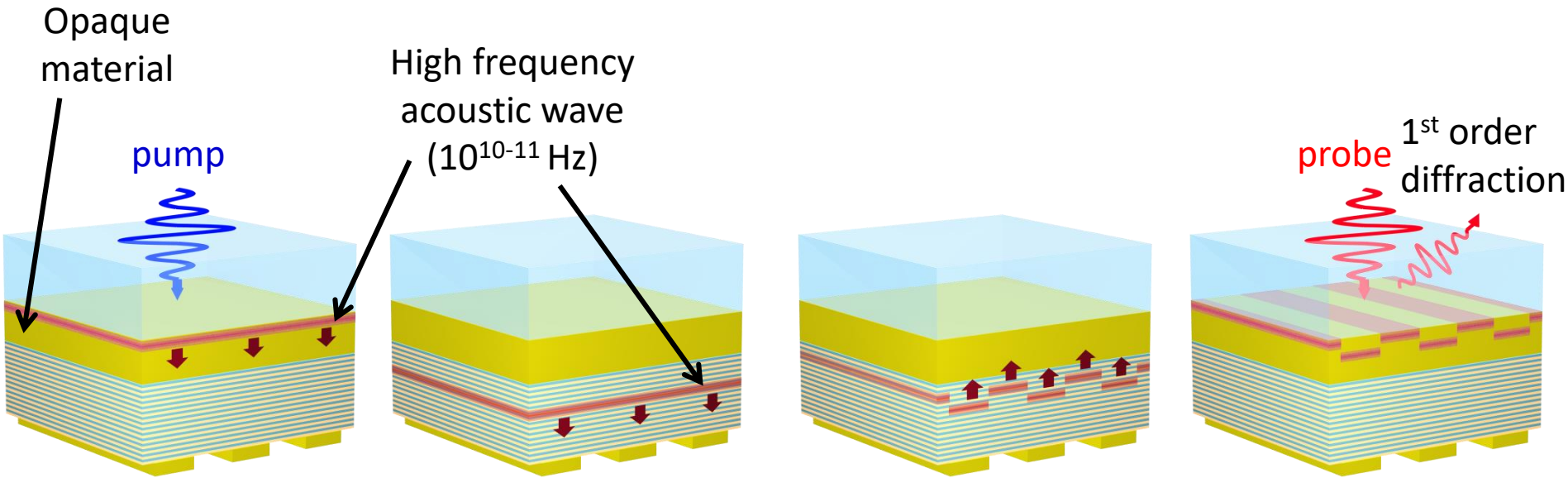
Motivation

Schematic of new 3D NAND memory chips



Problem: light cannot “see” grating through opaque layers

Possible solution: Photoacoustics



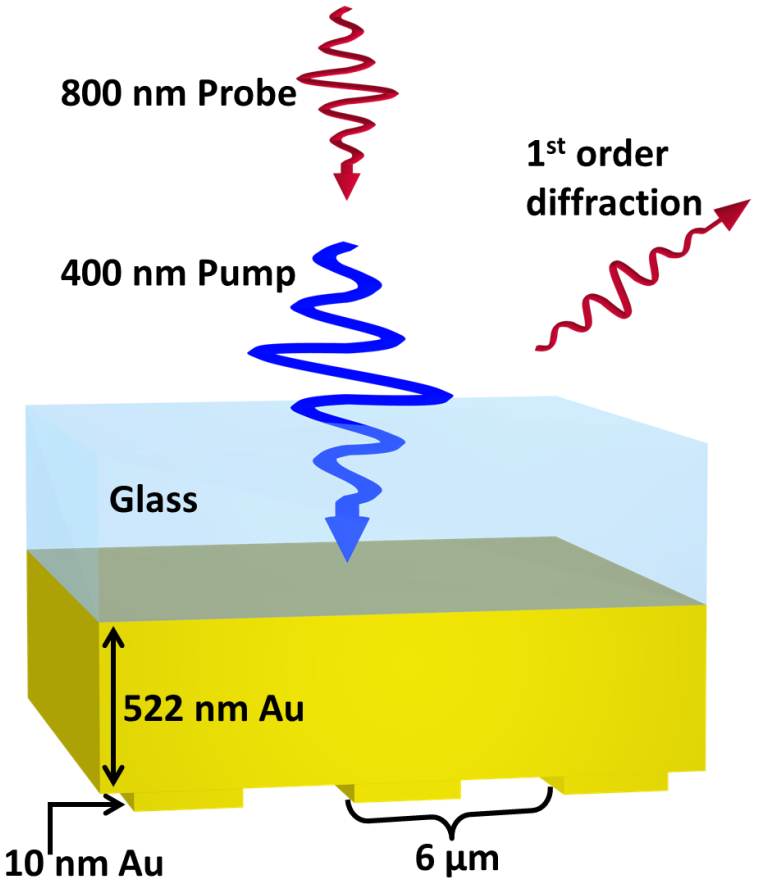
(1) Light absorption and acoustic wave generation

(2) Acoustic wave propagation

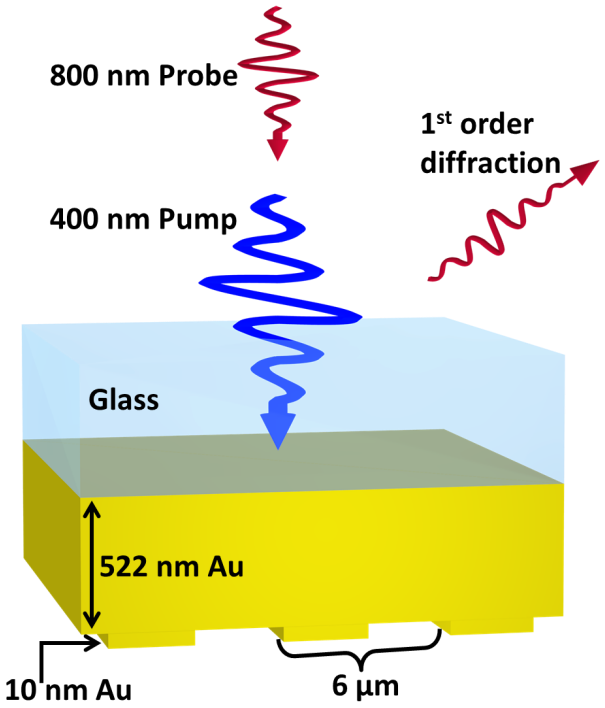
(3) Acoustic wave reflection off grating

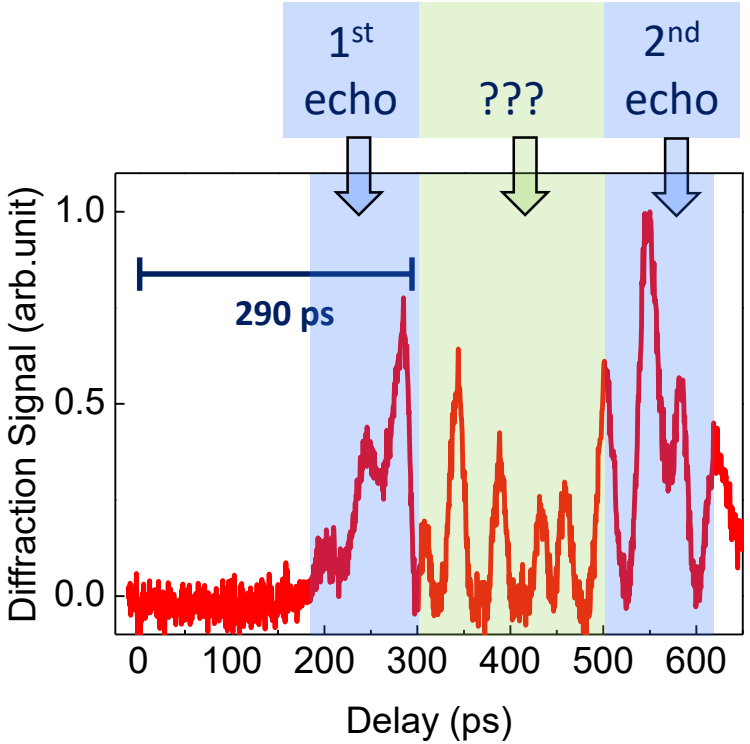
(4) Acoustic wave induced grating at surface

Acoustic echo from grating buried under Au



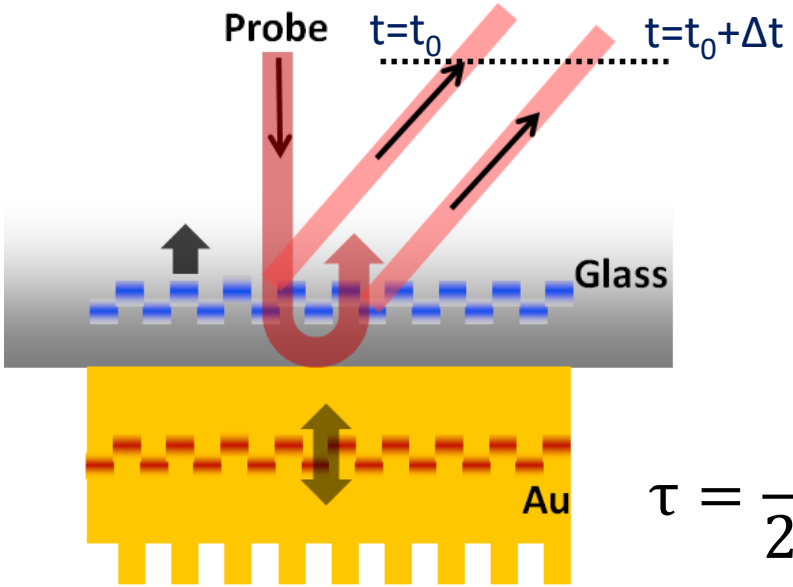
Acoustic echo from grating buried under Au



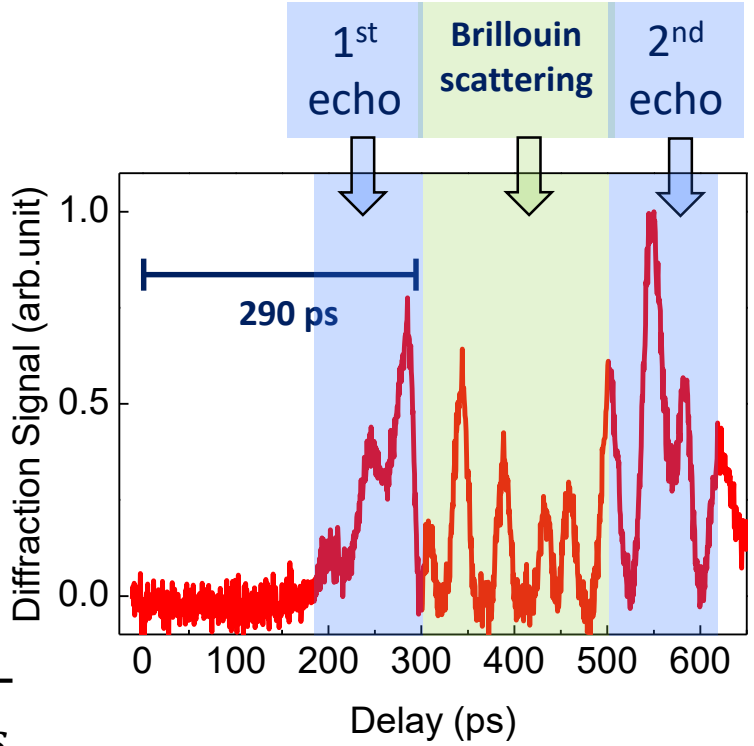


Acoustic echo from grating buried under Au

Brillouin scattering :Interference between diffracted, and delayed-diffracted beams



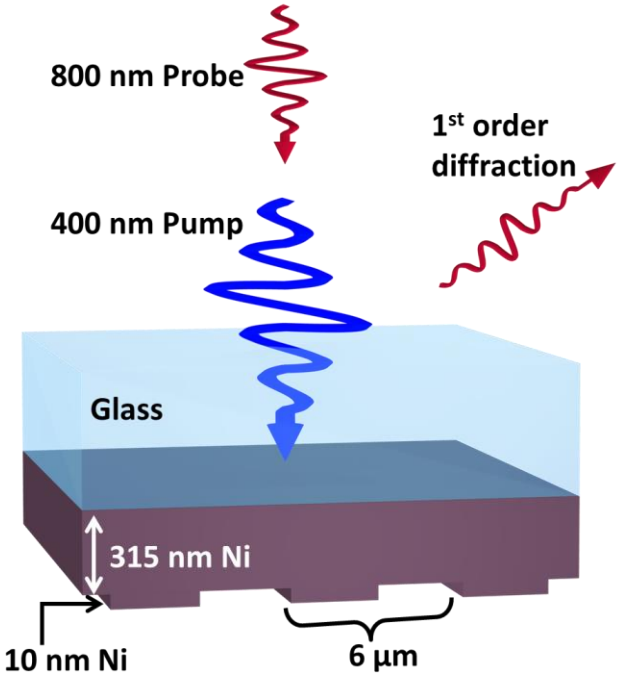
$$\tau = \frac{\lambda_{probe}}{2nv_{glass}}$$

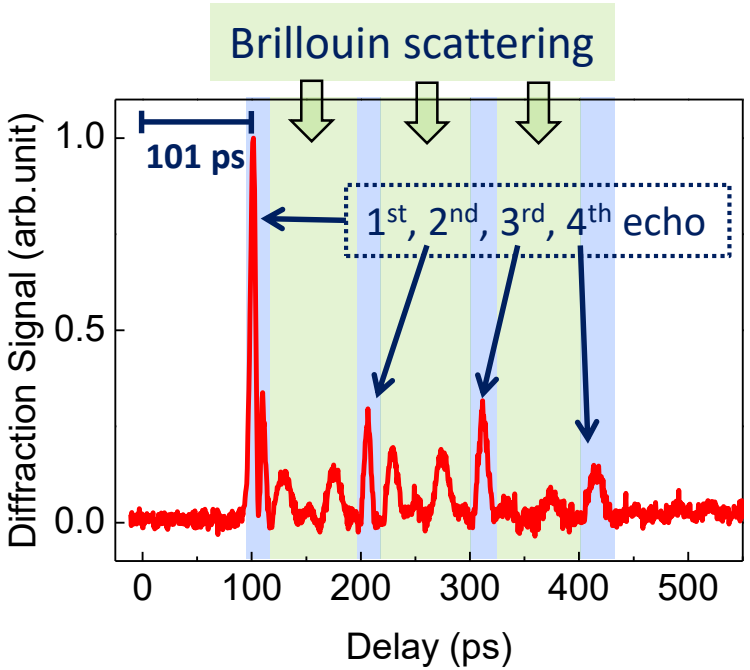


For 800 nm wavelength, the oscillation period is about 46 ps

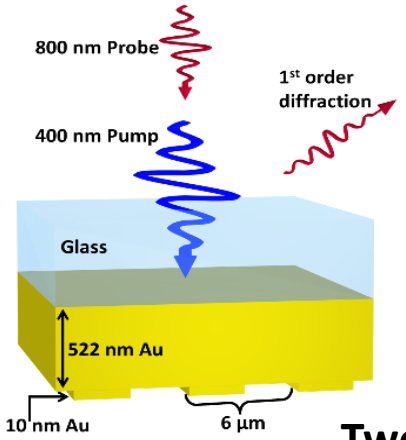
JAP 69, 3816 (1991)

Acoustic echo from grating buried under Ni





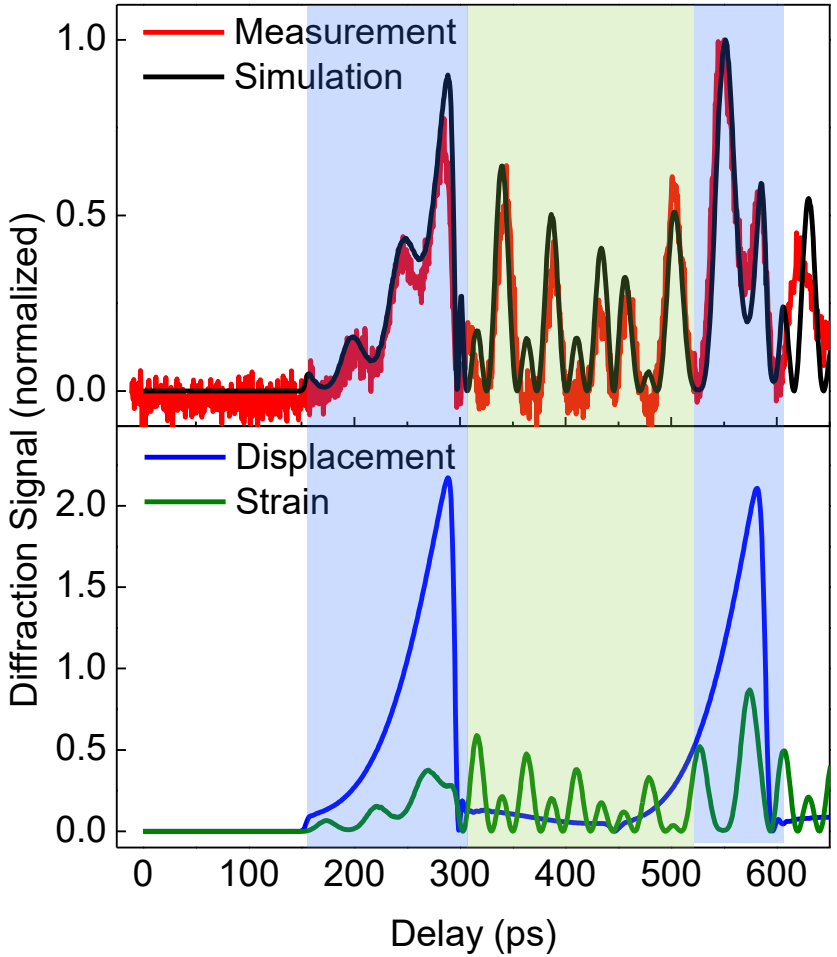
Experiment and Simulation



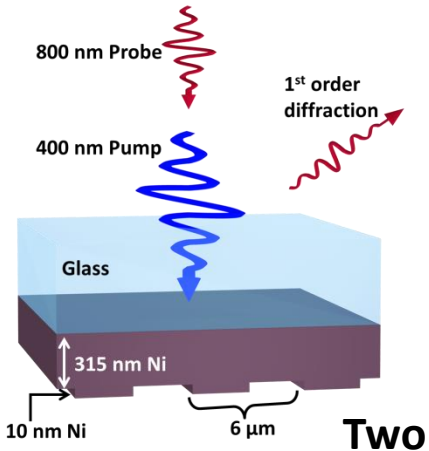
Two contributions

- Displacement of metal atoms at the metal/glass interface
- Change in refractive index of the glass substrate

Cannot simply add diffracted intensities, diffracted fields must be added coherently



Experiment and Simulation



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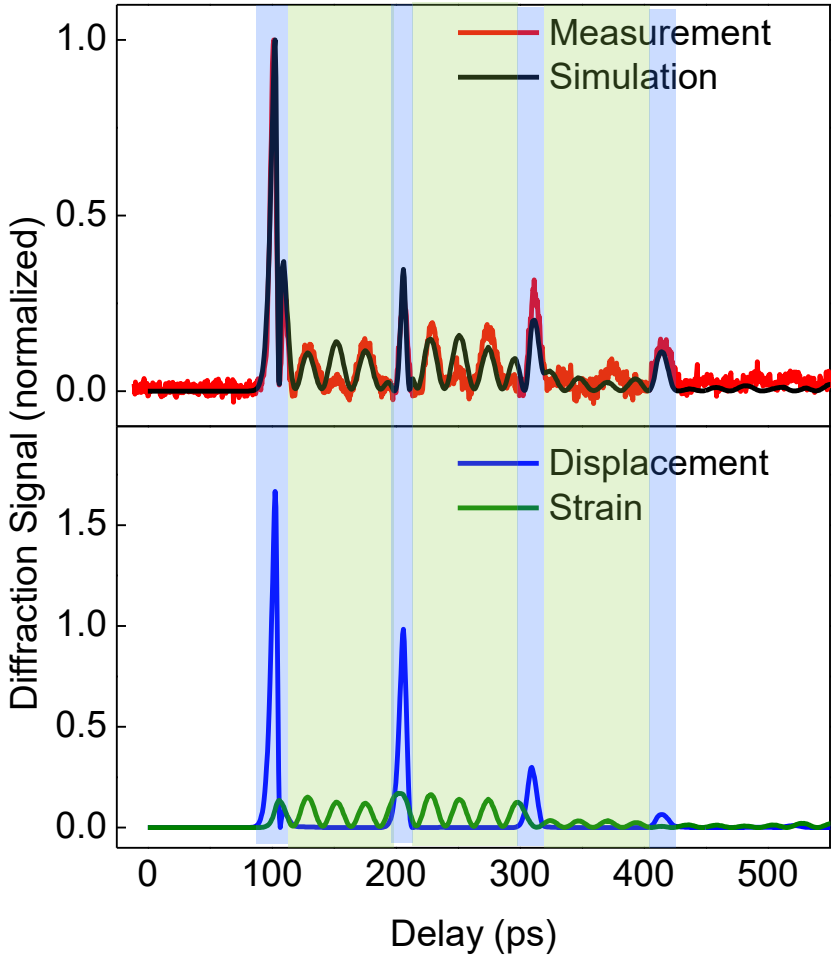
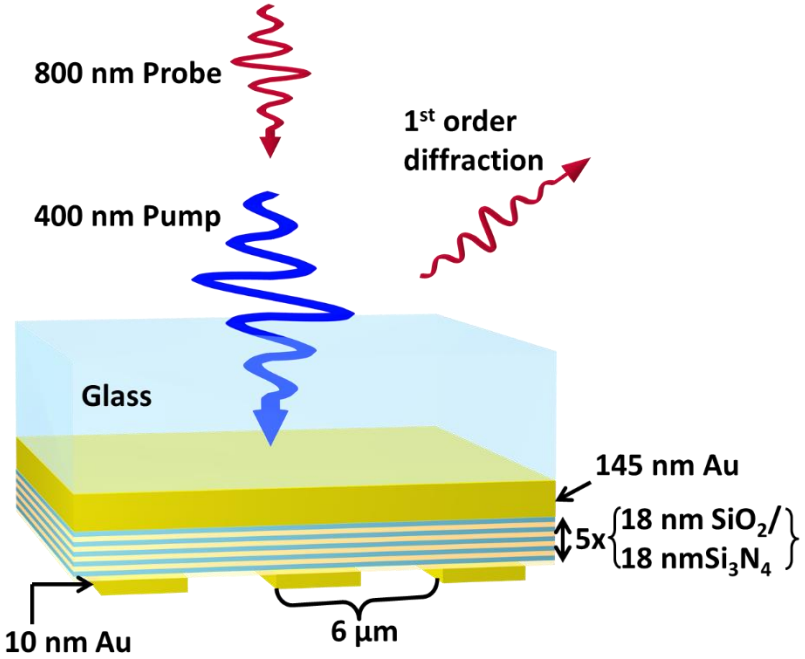
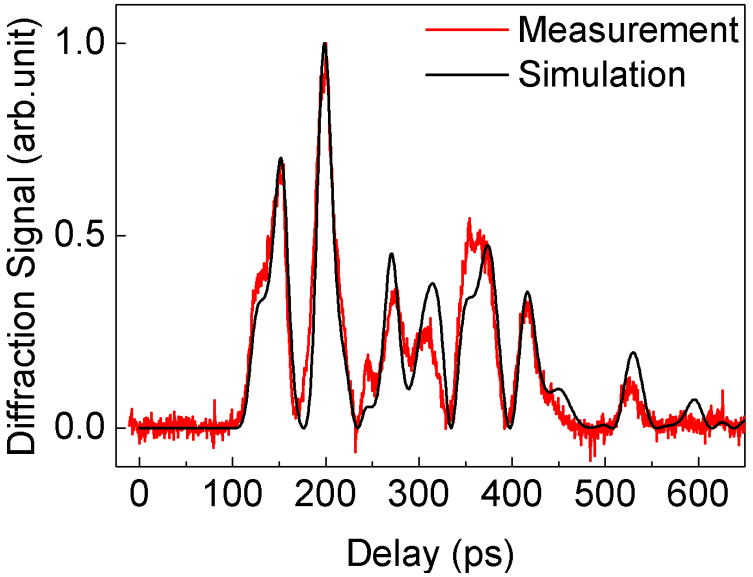


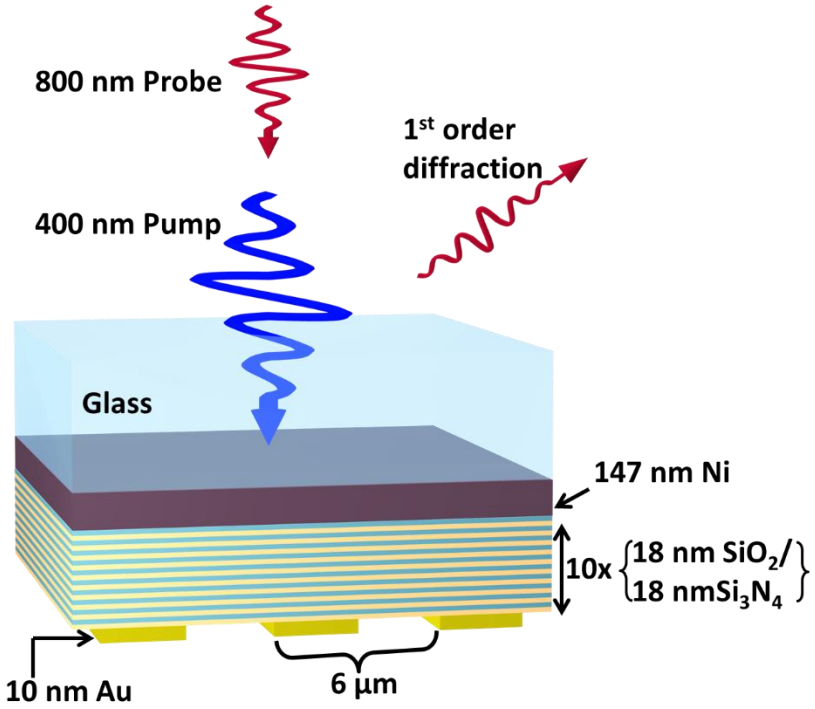
Acoustic echoes from gratings under metals and dielectric

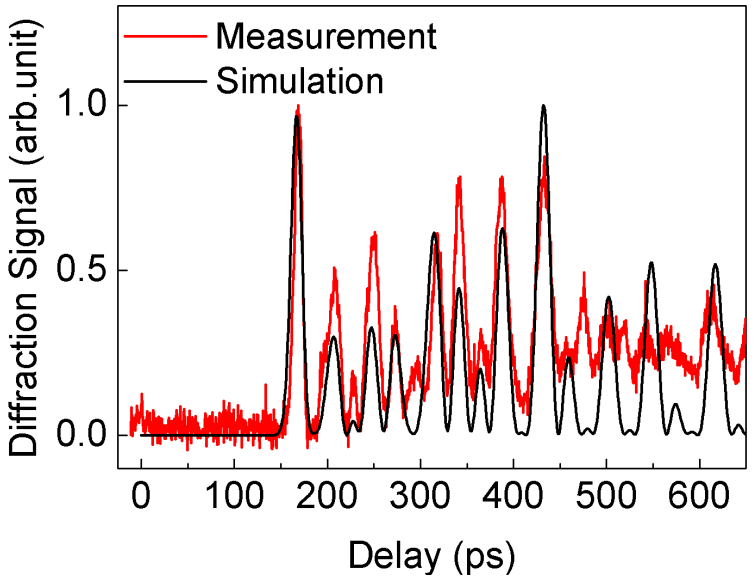




Grating still observed through multiple dielectric layers

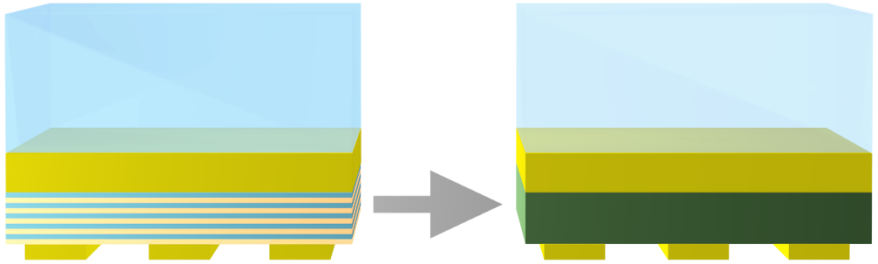
Acoustic echoes from gratings under metals and dielectric





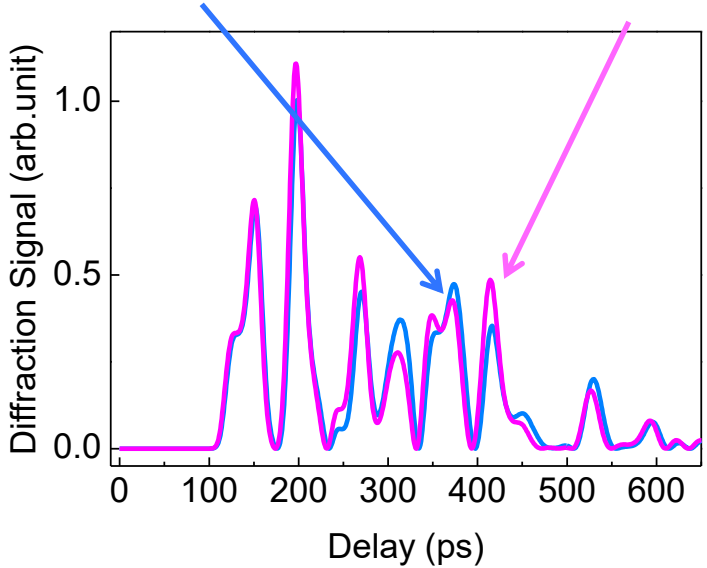
Grating still observed through multiple dielectric layers

Effect of multilayers in calculation

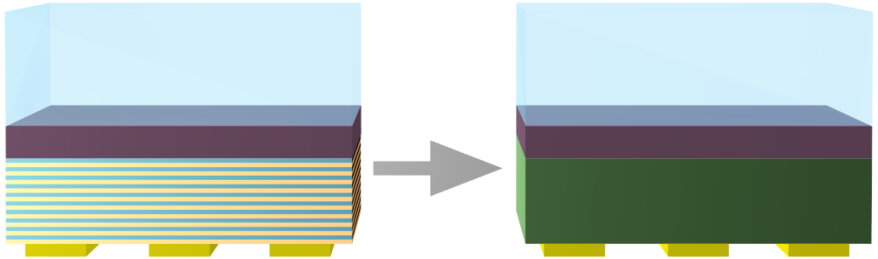


10 dielectric layers → single, time averaged medium

Acoustic wave "sees" an equivalent time-average medium rather than multiple layers.

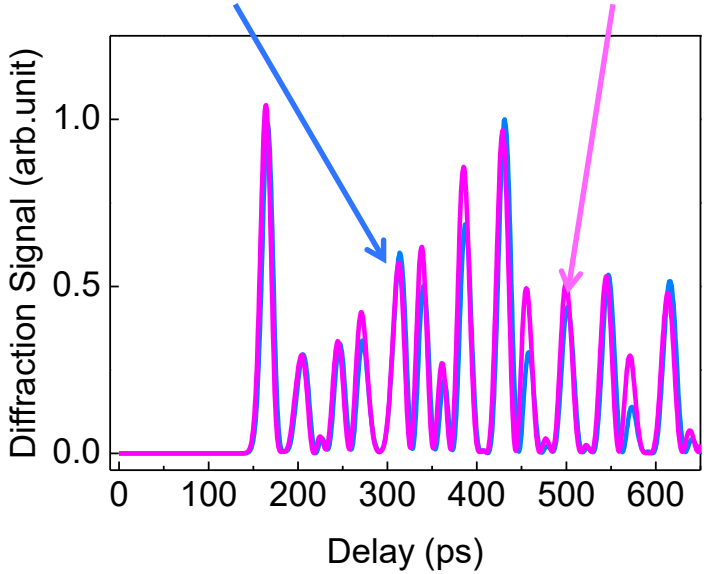


Effect of multilayers in calculation



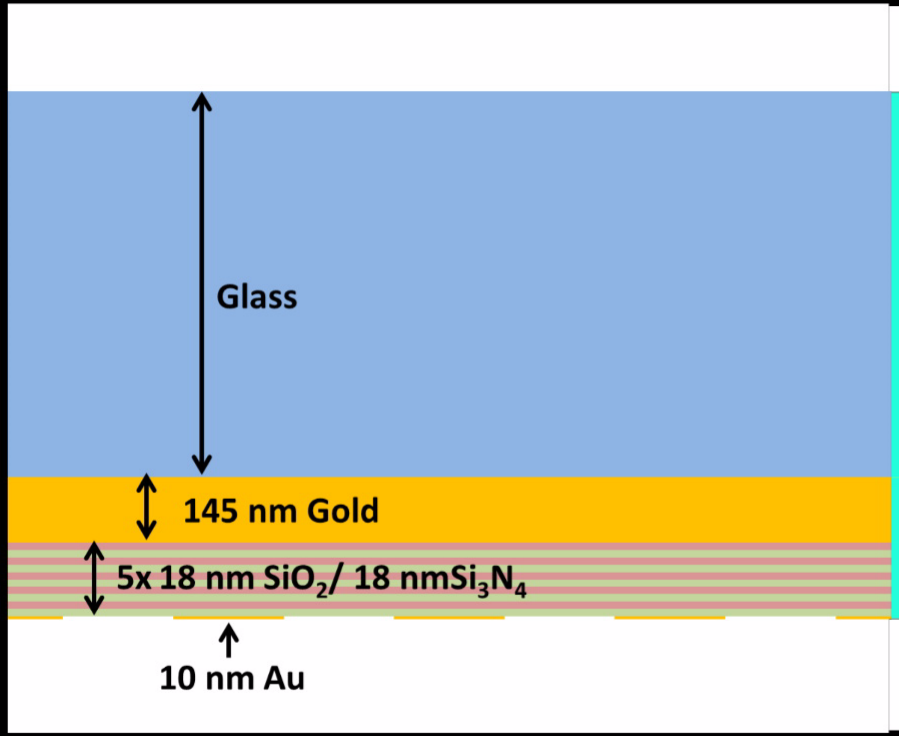
20 dielectric layers → single, time averaged medium

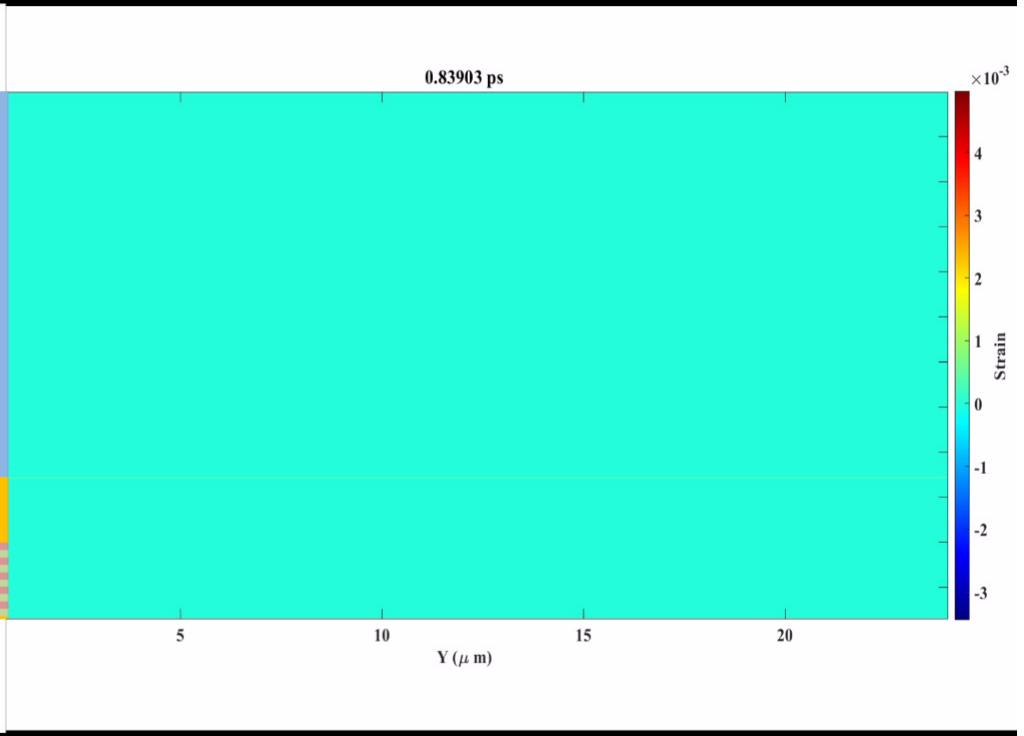
Acoustic wave "sees" an equivalent time-average medium rather than multiple layers.



Multiple dielectric layer don't prevent us from using this technique in real-life semiconductor industry applications.

Strain inside the Au multilayer sample





Summary

- Detection of gratings buried underneath optically opaque metal/dielectric layers through its acoustic copy.
  - Grating underneath flat layer of Au and Ni.
  - Au grating underneath samples similar to a 3D NAND structure.
  - Multiple dielectric layers have very little effect on the shape and strength of diffracted signal.

Acknowledgements

Group members:
Guido de Haan
Thomas Meijvogel

From ASML:
Bas Goorden
Simon Huisman

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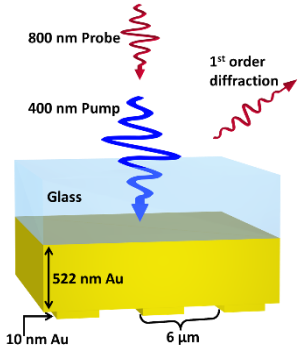
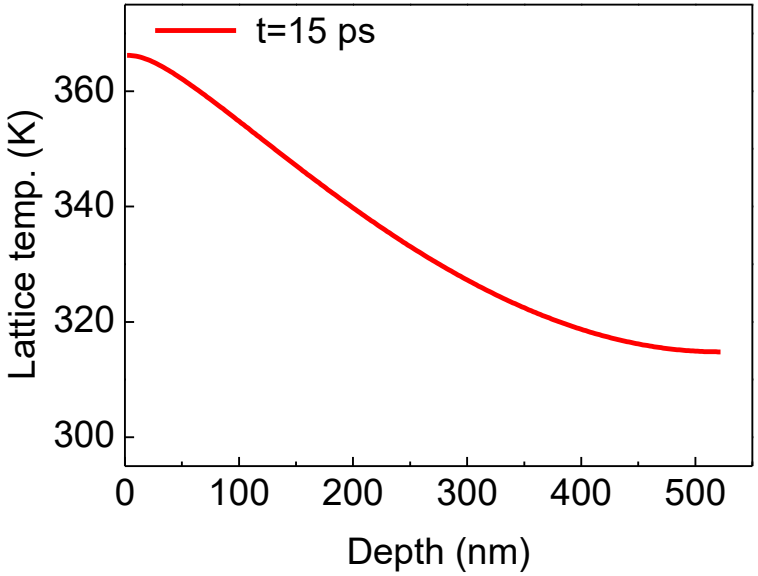
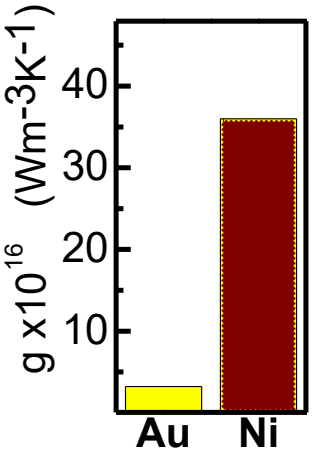
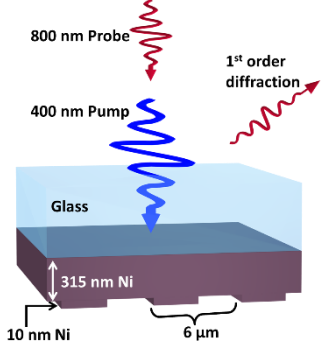
Optical excitation of Au and Ni layers

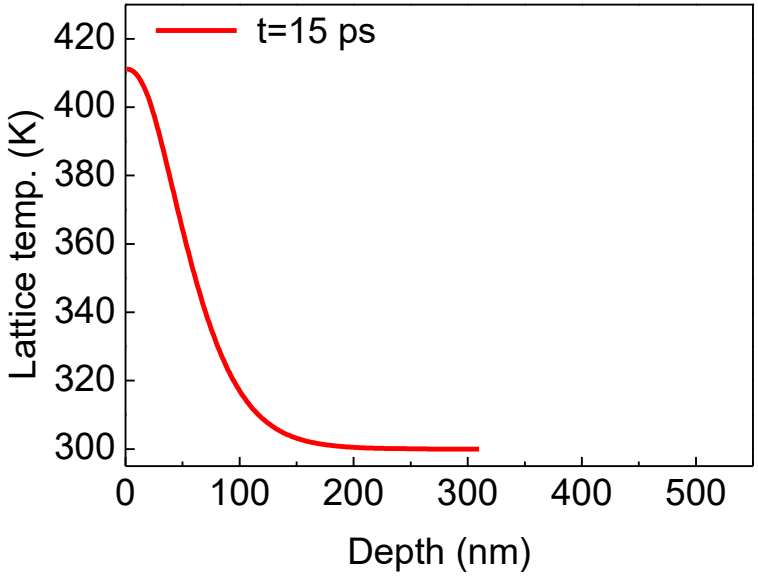






Electron-phonon constant of Au and Ni





Optical energy is deposited in smaller volume for Nickel, hence contains higher frequencies