Mirror, mirror on the wall, who has the lowest noise of them all?

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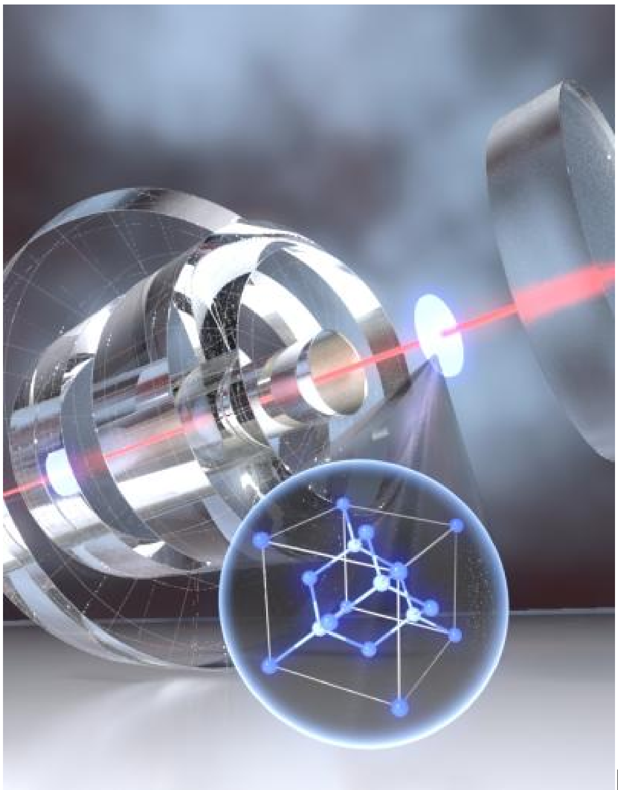

Researchers in Vienna and Boulder demonstrate a leap forward in optical coating technology

Although it may not be immediately obvious, the mechanical properties of optical components have a significant impact on the performance of lasers employed in precision sensing applications. Currently, the mechanical damping of such components, and the inherent mechanical fluctuations they generate, present a roadblock to further advancement of ever more precise measurements of time and space. For the past decade, researchers in the precision measurement community have been searching for a solution that allows for the development of high-reflectivity mirrors with simultaneously high mechanical quality. Now an international collaboration of scientists from Vienna, Austria and Boulder, Colorado, USA has demonstrated a novel technology for producing mirrors with a tenfold reduction in mechanical loss. The work, reported in Nature Photonics, represents an entirely new approach for generating high-quality optical coatings, key components of state-of-the art laser systems for precision measurement.

Combining aspects of semiconductor mirrors borrowed from surface-emitting diode lasers, an epitaxial layer transfer technique gleaned from advance nanofabrication processes, and an in-depth knowledge of mechanical losses gained from the field of cavity optomechanics, the researchers in Vienna realized a novel "crystalline coating" technology. The unprecedented improvement in mechanical quality, verified by the world-renowned experts in precision measurement in Boulder, arises from the intrinsic order of the high-quality semiconductor materials used to fabricate the mirrors. The development of such materials was historically driven by advances in microelectronics and photonics, enabling the technologies we interact with every day: high-speed integrated circuits, diode lasers for telecommunications, etc. Previously, the major impediment to utilizing such materials in general optics applications was two-fold: On the one hand, optical surfaces are in many cases curved, which presents a problem for direct crystal growth techniques, and on the other hand,typical optical substrates are made of glass with an amorphous structure that lacks the order required for seeded crystal growth. Circumventing these limitations, the researchers came up with a microfabrication process to separate and then bond high-quality single-crystal films onto curved glass substrates.

The mirror technology described in the manuscript promises to accelerate progress in the development of narrow linewidth laser sources for use in precision measurement systems, spanning time keeping with optical atomic clocks, as well as fundamental physics research involving precision tests of relativity, cavity quantum electrodynamics, and quantum optomechanics. Moreover, leveraging advanced semiconductor production techniques, there is a clear path to implementing large area crystalline coatings in astronomical endeavors, such as gravitational wave detectors. According to Professor Ye, "The development of highly phase coherent optical sources is a key technology that impacts a vast range of scientific explorations. In our own lab, we are able to demonstrate the most stable optical atomic clock thanks to these narrow linewidth lasers, and the progress is marching on!"

"The collaboration with Jun's group was fantastic," states Garrett Cole, who, along with Wei Zhang, is the lead author on the work. "They not only had the courage to take on an unproven technology, but also the ability to tackle a tremendously difficult task: quickly achieving thermally limited noise performance with their characterization system and verifying the high mechanical quality of our mirrors." Following this initial demonstration, the scientists are already hard at work to further improve the technology. Going forward, they plan to combine their novel coatings with the previously demonstrated single-crystal silicon cavity developed by researchers at JILA and PTB in Braunschweig, Germany (see "The World's Most Stable Laser," September 2012: http://www.nist.gov/pml/div689/new-ultrastable-laser.cfm [1]). In combination, an all crystalline cavity (comprising crystalline coatings, substrates, and spacer) would enable world-record stability and hence a new milestone in laser technology.

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