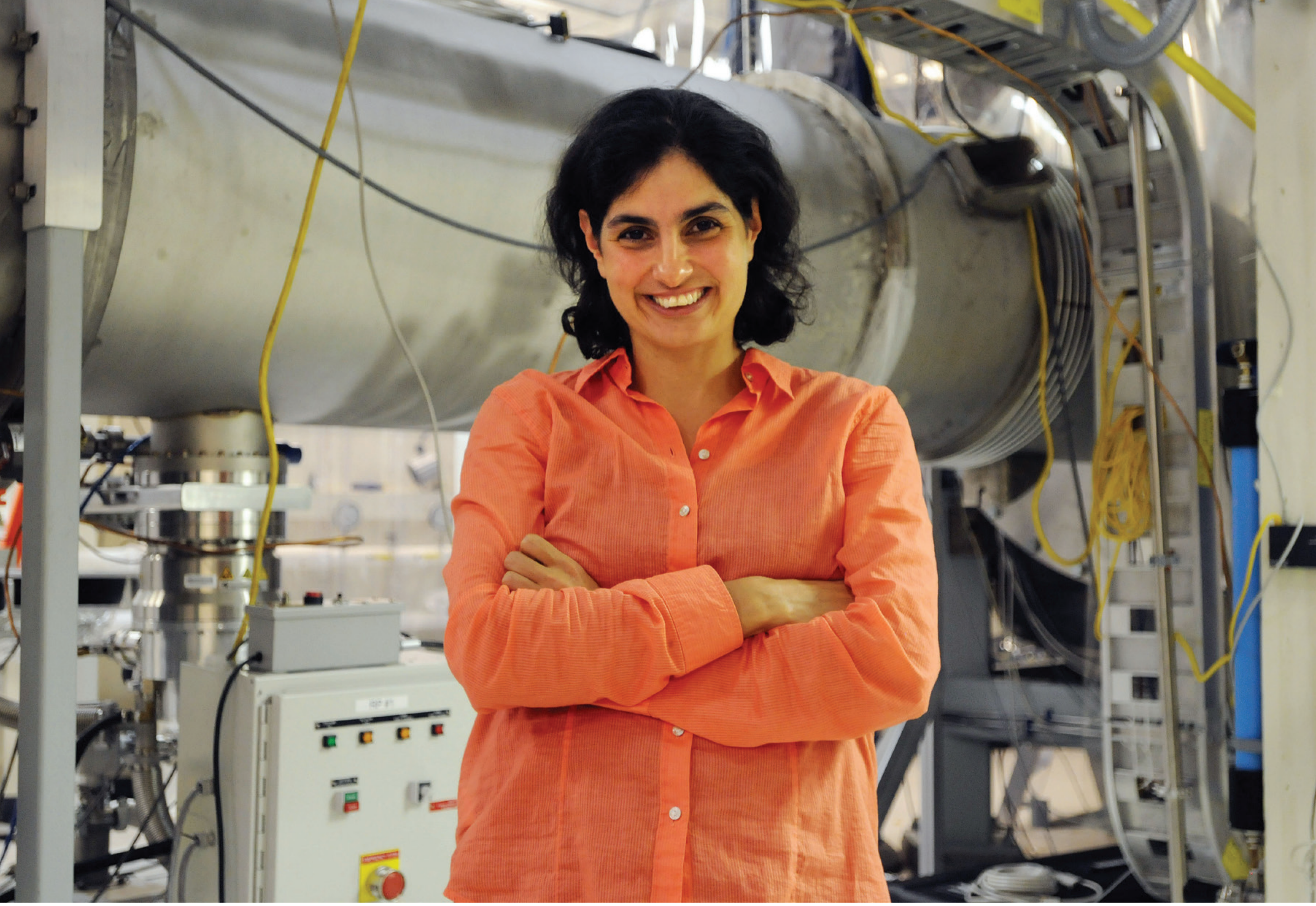

Darren McCollester/MacArthur Foundation

CONVERSATIONS

Q&A with 2017 CLEO Plenary Speakers

The Conference on Lasers and Electro-Optics (CLEO), which takes place 14 to 19 May in San Jose, California, USA, will once again unite the optics and photonics community in all things laser science and technology. In gearing up for this year's conference, OPN spoke with three of this year's plenary speakers, OSA Fellows **Nergis Mavalvala**, **Ataç Imamoglu** and **Ursula Keller**, to learn more about their talks.

Nergis Mavalvala

Massachusetts Institute of Technology, USA

Gravitational-Wave Detectors of the Future: Beyond the First LIGO Discoveries

Q. From the time you first started with the LIGO team to now—and beyond—how has the technology used in the project changed, and how will it continue to change?

In 1972, Rainer Weiss of the Massachusetts Institute of Technology, USA, made the first proposal for technically viable kilometer-scale laser interferometric gravitational-wave detectors. The ideas in that proposal became the basis for interferometric gravitational-wave detectors worldwide and led to the Laser Interferometer Gravitational-wave Observatory (LIGO) in the United States. Initial LIGO spanned the late 1990s to 2010 and used state-of-the-art technologies from the preceding decade. Advanced LIGO relied on similar principles, but with remarkable advances in certain technologies.

Some examples of quantum leaps in technical performance include

“Advanced LIGO will continue to improve as we innovate and introduce further enhancements.”

—Nergis Mavalvala

“What makes $MoSe_2$ remarkable for a physicist is its reduced dielectric screening.”

—Ataç Imamoglu

“Stabilized frequency combs have a major impact in many new application areas.”

—Ursula Keller

improved vibration isolation, lower-mechanical-dissipation materials, and laser light sources. Initial LIGO used (for its light source) a 10-W continuous-wave (CW) laser with a single-power amplifier stage. Advanced LIGO will deploy an 180-W CW laser with multiple amplifier stages as part of its final design (LIGO now uses 25 to 30 W). Initial LIGO used mostly passive vibration isolation, while Advanced LIGO’s seismic isolation platforms include hundreds of active isolation loops, allowing isolation to lower frequencies where vibrations can be greatest.

To filter out displacement (or force) noise, the mirrors of LIGO are suspended as pendulums. In Initial LIGO, these pendulums comprised metal wires, which introduce thermal noise due to mechanical dissipation in the wire. This dissipation is material-dependent, so Advanced LIGO mirrors were suspended from fused silica fibers, leading to much lower thermal noise from the suspension system.

As we deploy remaining subsystems, the sensitivity of Advanced LIGO will continue to improve as we innovate and introduce further enhancements. For example, a technology that recently matured enough to deploy in Advanced LIGO is the use of squeezed vacuum states to improve the quantum optical noise limit. The gravitational-wave community is working on lower-dissipation optical mirror coatings, on improved vibration isolation techniques and on other technologies that will increase the sensitivity of the detectors over the coming decade. These improvements should lead to further discoveries—of binary neutron star collisions, possibly of gravitational radiation from supernovae, and most excitingly, of cosmic events unknown to humanity.

Ataç Imamoglu

ETH Zurich, Switzerland

Polaritons in Two-Dimensional Electron Systems

Q. Molybdenum diselenide is an inorganic compound and crystalline solid. Why has it stood out as a cavity-polariton material in studying interactive bosons?

Molybdenum diselenide ($MoSe_2$), along with other transition-metal dichalcogenides, is a layered material with coupling between the monolayers due to weak van der Waals bonds. Consequently, it is easy to isolate atomically thin $MoSe_2$ and study its optoelectronic properties.

Alternatively, it is possible to combine a monolayer of $MoSe_2$ with layers of other transition-metal dichalcogenides to form heterostructures. This is a completely new, bottom-up approach to form semiconductors with new photonic or electronic functionalities.

What makes $MoSe_2$ remarkable for a physicist is its reduced dielectric screening, which results in more than an order-of-magnitude increase in exciton and trion binding energies, as well as exciton-photon coupling strength, resulting in the formation of robust cavity polaritons. This robustness, together with the possibility to construct requisite heterostructures for charge control, allows us to study the formation of many-body optical excitations between polaritons and a degenerate electron or hole system.

Ursula Keller

ETH Zurich, Switzerland

Ultrafast Solid-State Lasers: A Success Story with No End in Sight

Q. You call ultrafast solid-state lasers a "success story with no end in sight." How did this technology become so successful?

There is motivation to make reliable turnkey ultrafast lasers, since we know they are an important tool with many uses. For example, while I was a Ph.D. student, we used lasers to learn how to understand high-speed semiconductor integrated circuits. The same motivation was then repeated and emphasized at while I was at Bell Labs, USA, during the early 1990s, for use with optical interconnects, optical clocking and optical computing. These were all hot topics at that time.

At Bell Labs, I combined my expertise and interest in both semiconductor materials and diode-pumped solid-state crystalline lasers. This multidisciplinary approach allowed me to create a unique solution that also worked better for practical applications. In the meantime, most ultrafast industrial lasers have a semiconductor saturable absorber mirror inside.

Ultrafast lasers have important industrial applications ranging from precision micromachining, ophthalmology, microscopy and imaging to lidar, continuum generation, optical communication and frequency metrology. Power scaling of ultrafast diode-pumped ytterbium-doped thin-disk lasers has enabled unprecedented performance with several hundred watts of average output power, and has the potential to reach the kilowatt level in the future.

It is well known that frequency combs are generated from ultrafast lasers. However, normally these frequency combs aren't stable and need additional stabilization for the two degrees of freedom: comb spacing (i.e., pulse repetition rate) and comb offset (i.e., carrier-envelope offset phase). While comb spacing was stabilized earlier at Stanford University, USA, in the 1980s, the comb offset was an unresolved problem until we offered a solution in late 1999. Stabilized frequency combs have a major impact in many new application areas including precision frequency metrology, optical clocks, high-field physics and attosecond pulse generation. OPN