Photonics

Time-reversing a laser: What it means and why it's important.

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Abstract: Over a decade ago an overlooked symmetry of Maxwell's equations coupled to matter was recognized, a relationship between a laser at threshold and a perfectly absorbing resonator. The threshold condition for lasing is the point at which gain balances loss, and the system self-organizes to oscillate coherently at a specific frequency in the highest Q electromagnetic mode. At this special point the system supports a purely outgoing solution of the Maxwell wave equation at a real frequency but with negligible amplitude, heralding the turn-on of a steady-state source of coherent radiation. Time-reversing this threshold lasing equation maps the laser system to another physical realizable electromagnetic system, one in which the time-reflected lasing mode is incident on an identical resonator, except that absorption loss replaces gain, and the purely incoming wave is perfectly trapped by interference and eventually absorbed without scattering. This mapping implies that under very general conditions, any complex structure can be made to absorb perfectly at a specific frequency, if a specific *adapted* input wavefront is imposed and the loss is appropriately tuned, a phenomenon now known as Coherent Perfect Absorption (CPA). While CPA was proposed for classical electromagnetic waves, the effect occurs for all of the linear classical wave equations of physics, and has nonlinear generalizations as well. Moreover, while CPA describes perfect capture and transduction of waves, the theory pointed the way to an even more general theory of reflectionless scattering of appropriate adapted wavefronts ("reflectionless scattering modes", RSMs). This theory applies to quantum waves as well, and provides a new framework to explore the control and routing of waves via interference in guided and even open geometries. I will review a few dramatic experimental and technologically interesting applications of CPA and RSM.

Biography: A. Douglas Stone is Carl A. Morse Professor of Applied Physics, and Professor of Physics at Yale University, where he joined the faculty in 1986. Since becoming a full professor in 1990, he has served as Chair of Applied Physics (1997-2003, 2009-2015), Director of Yale's Division of Physical Sciences (2004-2009), and Deputy Director of the Yale Quantum Institute (2015-present).

Stone is a theoretical physicist with research interests in condensed matter and optical physics. He has co-authored over 165 research publications, which have been cited over 28,000 times, with an h-index of 74 and holds four patents for optical devices. He was a pioneer in the field of mesoscopic physics, describing systems intermediate between bulk solids and individual atoms or molecules, where novel quantum effects appear. Subsequently he worked on problems relating to the effects of chaos in quantum and electromagnetic systems, and was the first to introduce and study lasers with ray-chaotic resonators. His current work continues to focus on lasers, and other photonic systems with complex geometry and gain and loss. He is a recipient of the McMillan Award of the University of Illinois at Urbana for "outstanding contributions to condensed matter physics" for his research demonstrating "universal conductance fluctuations" in mesoscopic conductors. He was awarded the 2015 Willis Lamb Medal for Laser Science for his work on random and chaotic lasers, in collaboration with his colleague Hui Cao. His group developed Steady-state Ab initio Laser Theory (SALT), which is the first general formulation of laser theory set up to deal with arbitrary spatial complexity in a lasing structure efficiently, assuming steady-state operation. In 2010 he pioneered the concept of the Coherent Perfect Absorber (the time-reversed or "anti-laser"), and has recently generalized this framework to encompass a general theory reflectionless scattering of all linear waves. He is a Fellow of the American Physical Society and of the Optical Society of America, and is an Honorary General Member of the Aspen Center for Physics.

Stone earned his BA from Harvard in 1976, an MA from Balliol College, Oxford in 1978 (where he was a Rhodes Scholar), and a PhD from MIT in 1983 under the supervision of John Joannopoulos. He was a postdoc at IBM before coming to Yale.

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