been expected, given that it was derived for small non-equilibrium systems that do not even make transitions between equilibrium states. The usual caveats apply: the equality strictly holds only for an infinite number of realizations, convergence can be slow — and its extent hard to gauge, exponential weighting 'picks out' extreme values and thus potential experimental artefacts, and in general, it is not easy to unambiguously assign the instantaneous state of a system based on a series of measurements. But all of these things are almost certainly tractable and manageable. It is clear that our understanding of thermodynamics is far from complete — indeed, it seems that we are only just getting started!

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LASERS

Symphony of lights

It's now half a century since the invention of diode lasers, and today they are the most common type of laser, with countless applications in telecommunications, industry and medicine, as well as in everyday life, from laser pointers, supermarket scanners and DVDs, to spectacular laser shows such as Hong Kong's daily 'symphony of lights' (pictured).

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In autumn 1962 — two years after Theodore Maiman's demonstration of stimulated optical radiation in ruby, the first laser — groups at General Electric, IBM and MIT's Lincoln Laboratory reported coherent light emission from gallium arsenide p–n junctions (*Phys. Rev. Lett.* **9,** 366–368; 1962 and *Appl. Phys. Lett.* **1,** 62–64, 91–92; 1962, respectively). The earliest diode-laser prototypes operated in pulsed mode at cryogenic temperatures, were highly inefficient and had very short lifetimes. Only in the 1970s was continuous-mode operation at room temperature achieved, thanks to the introduction of double heterostructures — and hence semiconductor lasers became both practical and commercial.

The first diode lasers emitted at infrared and visible–red wavelengths. Today, semiconductor lasers cover the entire visible and near-infrared spectrum — a true symphony of lights. But reaching wavelengths in the ultraviolet region has proved a challenge because of the difficulty of manufacturing suitable gallium-nitride or indium-gallium-nitride structures — the ideal semiconductors for blue-light emission. The first efficient blue diode laser was demonstrated only twenty years ago (S. Nakamura and T. Mukai, *Jpn. J. Appl. Phys.* **31,** L1457–L1459; 1992).

Lasers have had a deep impact on physics, providing a new tool with which to probe and manipulate matter at the atomic level. Semiconductor lasers are tunable, widely available and easy to use, and hence have led to the development of experimental techniques such as laser spectroscopy and interferometry, or laser cooling and trapping, enabling the exploration of the ultracold domain and the creation of new quantum states of light and matter. This enhanced understanding of the physics of atoms and photons has in turn led to a new generation of technologies such as atomic clocks, the world's most accurate time and frequency standards; optical tweezers, for the precise manipulation of microscopic objects; and quantum-communication and quantum-metrology applications.

Meanwhile, a related technology in the form of the solid-state maser has lagged behind. As in the early days of semiconductor lasers, solid-state masers have always required cryogenic cooling and hence lacked the desired practicality. But a solid-state maser operating in pulsed mode at room temperature has now been reported (M. Oxborrow *et al. Nature* **488,** 353-356; 2012), so masers, with the promise of new applications and perhaps new physics, may at last be catching up with their diode-laser cousins.

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