Considerations on Micro- and Nanolaser Physics

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The process of laser size reduction has prompted fundamental questions about the physics of small systems and the threshold transition that occurs within them. Questions have arisen regarding the buildup of optical coherence, which is associated with the transition from random photon emission to the predominance of stimulated processes. These questions have emerged as fundamental concepts that require elucidation in order to answer the technological demand for quality characterization of the smallest sources. Furthermore, intriguing aspects related to the dynamics of micro- and nanolasers, accompanied by somewhat unexpected outcomes, are also under consideration. The identification of the threshold has been a vexing challenge in nanolaser research for decades. The difficulties associated with fundamental properties, coupled with the experimental challenge of measuring extremely low photon fluxes at ultra-low power levels, have contributed to the prolonged uncertainty surrounding this issue. Recent results indicate that the various concepts employed to identify threshold in macroscopic lasers (*e.g.*, onset of coherence and gain-loss balance) do not align in very small devices. Consequently, it is necessary to recognize an ensemble of thresholds at the micro- and nanoscale. Furthermore, the technological constraints resulting from the limited bandwidth of ultrasensitive linear detectors necessitate photon-counting-based schemes that rely on photon statistics and accurate models. The presentation will review the various issues, highlight recent results, and propose lines of investigation.