“A fresh look at continuous-wave lasers: How they really work!”

Abstract:
This lecture describes the operation principle of a continuous-wave (cw) laser. In order to keep the photon rate equation and its solution simple, usually the spontaneous-emission rate is neglected with the argument that it is so much smaller than the stimulated-emission rate. The direct consequence is that in a cw laser the gain would equal the losses. Yet, additional implications are that the light emitted by such a laser would be a pure sine wave with an infinite coherence length, its linewidth would become a delta function, its *Q*-factor would assume an infinite value, the coherent photon number would build up and coherence would manifest itself inside the resonator only when pumping above the laser threshold, and the threshold inversion would depend only on the total resonator losses. None of these implications holds true for any laser that mankind has ever created. Starting from vacuum fluctuations, we consider spontaneous emission directly in the photon rate equation, thereby *a priori* avoiding all these inconsistencies. It is then straight-forward to see that in a cw laser the gain is smaller than the losses, a cw laser does not only have a finite linewidth that can be derived in a very simple manner, but also a finite *Q*-factor, as well as two laser thresholds which are both different from the commonly assumed “threshold inversion”. This work was performed in collaboration with Dr. Marc Eichhorn from the French-German Research Institute of St. Louis, France.