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Control of ring lasers by means of coupled cavities

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Coupling of optical cavities offers a means of controlling the properties of one cavity (e.g. a laser) by making adjustments to another, external cavity. In this contribution we consider a unidirectional ring laser (bow-tie laser) coupled to an external ring cavity. Using different configurations we can control the out-coupling from the ring laser thereby influencing the threshold and the circulating power in the different ring cavities. This may be used to obtain the best balance between the passive losses and a nonlinear loss such as e.g. conversion to the second harmonic of an optical parametric oscillator.

We have found that by quickly changing the phase of the feedback from the external ring it is possible to Q-switch the ring laser. Also, at certain values of the phase of the feedback in the external ring, instabilities in the total system occur and oscillations arise in the ring laser. This behavior is described by our theoretical models and confirmed experimentally. The theoretical description involves the solution of a set of transcendental nonlinear equations, one for the laser, one for the nonlinear optical process and one for the output coupling. The coupling is controlled by the transmission properties of the coupled Fabry-Perot-ring. The facilities of modern PC-based mathematics programs offer new possibilities for quickly and conveniently solving these equations and obtain new information on the complex behavior of coupled nonlinear systems.

We have specifically considered a bow-tie unidirectional ring laser coupled to an external triangular Fabry-Perot ring. At first we couple to an empty ring with an output mirror mounted on a piezo-driver. We vary the phase by means of a manual control box or an electronic signal generator. In this case we vary the apparent reflectivity of the coupling mirror. We can also adjust the phase of the return path such that the output is optimized. If the phase is made to change quickly, the ring laser is observed to Q-switch just by means of the variable phase control. We have also observed oscillations in the system at certain values of the phase.

In a further development we consider the coupled rings with a KTP-crystal inserted. The second harmonic generation now depends on the phase of the harmonic signal returned to the KTP-crystal. By varying the position of the pigtails, we can measure the effect of a phase variation in the harmonic feedback and optimize the efficiency of the nonlinear crystal. As in well known theoretically, the effect of feedback back the harmonic in the appropriate phase is an apparent remission in the conversion efficiency of the crystal.

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