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Anamorphic beam shaping of totally incoherent light

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We report on a series of experiments for anamorphic beam shaping of totally incoherent light beams. In all these experiments the goal is to improve the beam quality (or brightness) in one spatial direction on the expense of a reduced beam quality in the orthogonal direction (preserving the two dimensional beam brightness). The necessary coupling between the two orthogonal axes is performed with anamorphic optics. In the first configuration simple continuous optical elements such as a cylindrical lens at 45° to both axes was used. For more general transformations an array of micro Porro-prisms [1] or a properly designed retro-reflector array [2] were used. Finally, tapered reflecting light pipes were shown to yield the similar anamorphic transformations at the adiabatic limit.

The anamorphic beam shaping were applied for high resolution grating-based spectrometry for diffuse light where it reduced the beam divergence in the direction orthogonal to the grating grooves to yield a 12-fold improvement in the spectral resolution without any loss of light (see Fig. 1). It was also applied to anamorphic concentration of solar radiation beyond the one-dimensional thermodynamic limit (see Fig. 2).

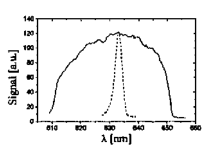

Fig 1. Measured spectral impulse response of a grating-based spectrometer with (solid curve) the anamorphic beam shaping and (dashed curve) without it.

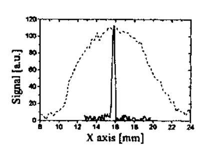

Fig 2.Measure x-cross section of a concentrated solar-like source with (dashed curve) and without (solid curve) anamorphic beam shaping

[1] N. Davidson, L Khaykovich, and E Hasman, Opt Lett. 24, 1835 (1999)
[2] N Davidson, L. Khaykovich, and E. Hasman, submitted to App. Opt. (2000).

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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 or operation 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 resonators.

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-drive. We vary the phase by means of a manual control box or an electronic signal generator. This in turn varies the apparent reflectivity of the coupling mirrors. We can for instance cause the laser to go below threshold by adjusting the phase of the feedback loop in such a way that the reflectivities of the coupling mirrors become high. 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 piezo-mirror, we can measure the effect of a phase variation in the harmonic feedback and optimize the efficiency of the nonlinear crystal. As is well known theoretically, the effect of feeding back the harmonic in the appropriate phase is an apparent increase in the conversion efficiency of the crystal.