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Low-Loss Mach-Zehnder Interferometer for Laser Frequency Selection

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Abstract. A low-loss Mach-Zehnder interferometer of a design proposed by Bergquist and Burkins is described. Replacing a commercial Fabry-Perot etalon with the Mach-Zehnder interferometer increased the single-mode output power of a ring laser operating with Styryl-9 dye by a factor 1.5.

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Narrowband, tunable lasers commonly use an intracavity Fabry-Perot etalon (FPE) for fine frequency control. Berquist and Burkins[1] have observed that the Mach-Zehnder interferometer (MZI) should be a superior intracavity frequency selector, since the MZI does not suffer from the walk-off loss which is inherent with the FPE. They also proposed an elegant MZI design which eliminates the partially transmitting coatings which lead to severe losses when a FPE is used in a high-power laser[2]. In this note we report that we have constructed a MZI along the lines suggested by Bergquist and Burkins and find that indeed it has lower loss than a commercial FPE.

The design of our MZI is shown in Fig. 1 (cf. Fig. 4 of Ref. 1). It comprises an uncoated fused quarz prism[3], which replaces the beamsplitters and one mirror of the classical MZI, and a high-reflecting dielectric mirror. The s-polarized incident ray is split at A into a reflected beam AD of relative intensity r and a refracted beam AC of relative intensity 1-r, which are recombined at B, after reflections at points D and C. A piezoelectric translator adjusts the spacing between mirror and prism, which determines the resonant frequency of the interferometer. Note that there exists a ray A'A which is neither displaced nor deviated by the ideal MZI and that consequently the MZI may be inserted into a laser cavity without affecting the alignment of the other cavity elements. In practice however a readjustment of the cavity was necessary, caused by the fabrication tolerances of the prism.

The fringe contrast of the MZI, i.e. the rejection of the off-resonant frequencies, is 4r(1-r), and the free spectral range is given by $\Delta\nu_{FSR}=c/\Delta l$, where Δl is the difference in the optical lengths of the paths ADB and ACB. Our design has $\Delta\nu_{FSR}=75$ GHz and a fringe contrast of 73% at the design wavelength of 830 mm; these values were chosen to match those of a FPE which we have found suitable for single-mode operation of a ring dye laser.

We have operated the MEZI in a ring dye laser of our own construction, using the dye Styryl-9. With a 2% transmitting output coupler, the insertion loss of the MZI was measured to be 20%, compared to 50% for a commercial FPE, thus demonstrating the expected lower loss of the MZI. For one year the ring laser incorporating the MZI has been in routine use for Doppler-free spectroscopy of Cs[4], with only slight realignments of the MZI.

Recently it came to our attention that a similar MZI proved to be efficient as a mode selector for a ring laser with the dye Rh6G[5]. The performance was comparable to our device.

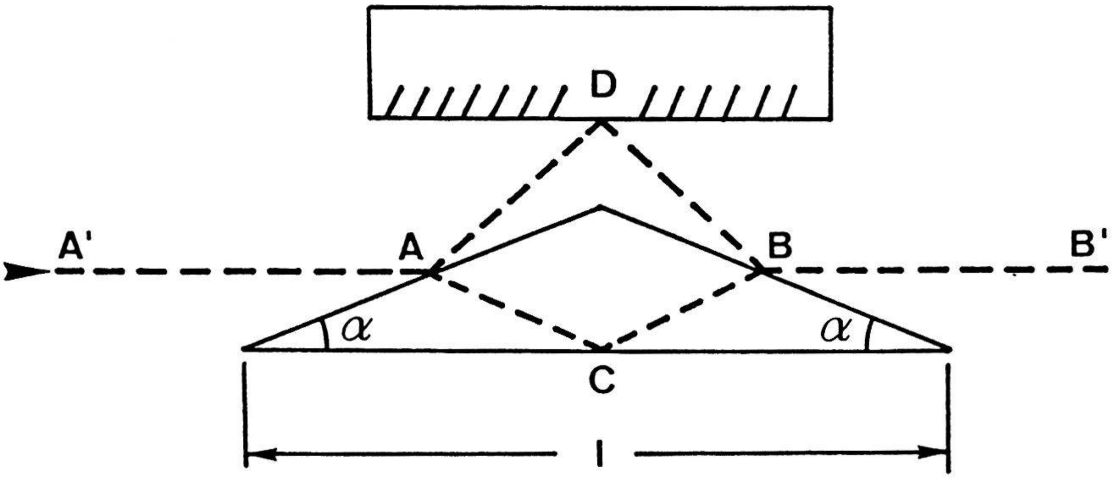

Figure 1: Cross section of the MZI. Light traverses the interferometer along the paths A'ACBB' and A'ADBB'. The prism dimensions are $l = 19.7$ mm and $\alpha = 22.5^\circ$.

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