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Aberration influence and active compensation on laser mode properties for asymmetric folded resonators

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ABSTRACT

We demonstrate the influence on mode features with introducing typical intracavity perturbation and results of aberrated wavefront compensation in a folded-type unstable resonator used in high energy lasers. The mode properties and aberration coefficient with intracavity misalignment are achieved by iterative calculation and Zernike polynomial fitting. Experimental results for the relation of intracavity maladjustment and mode characteristics are further obtained in terms of S-H detection and model wavefront reconstruction. It indicates that intracavity phase perturbation has significant influence on out coupling beam properties, and the uniform and symmetry of the mode is rapidly disrupted even by a slight misalignment of the resonator mirrors. Meanwhile, the far-field beam patterns will obviously degrade with increasing the distance between the convex mirror and the phase perturbation position even if the equivalent disturbation is inputted into such the resonator. The closed-loop device for compensating intracavity low order aberration is successfully fabricated. Moreover, Zernike defocus aberration is also effectively controlled by precisely adjusting resonator length, and the beam quality is noticeably improved.

1. Introduction

Excellent beam quality is a key prerequisite in present laser technique and application. The characteristics of unstable oscillators with large and uniformly filled mode volume, uniform optical phase, good fundamental transverse mode selection and convenience of output coupling have made it a prime candidate for high-energy laser systems [1,2]. Such structure can also suppress the high order mode to obtain high beam quality. Relative investigations indicate elsewhere that in many situations the brightness of lasers can be significantly increased by adopting an unstable rather than a stable resonator [2–4]. However, High output power and high beam quality are two contrary characteristics for conventional lasers. The problems always affect the beam properties; mainly include the cavity geometry misalignment and thermal distortion, inhomogeneity and thermal effect of the gain medium, etc. [5–7]. So especially for a high-energy oscillator, the eigenmode features shall be degraded distinctly by such perturbations.

Under the premise of limited output energy, some methods are developed to improve mode characteristics such as phase conjugation [8], adaptive optics (AO) [9], temporal and spatial filtering [10], and so on [11] in recent years. However, these methods have the limitations by relatively more complex structures and higher cost, e.g. the maximum correction stroke of AO device is usually less than several microns, and mode features will degrade rapidly once AO device reaches its stroke limit. Moreover, the compensation capability for lower order aberration e.g. the Zernike phase tilt is very limited.

Because unstable resonators are usually used in high-energy laser, it is very important to illustrate the effect on the beam quality and mode distribution with typical intracavity perturbation such as phase-tilt, defocus and astigmatism, which is the basis to further solve the problem of intracavity compensation and fabricate the aberration control device [12]. However, experiment of unstable resonators with typical intracavity perturbation on the output mode has been few and fairly limited in scope. In fact, it is not very explicit currently because beam wavefront has not been decomposed to Zernike polynomial aberration, which is not beneficial to accurately wavefront compensation [13,14].

We analyze the mode characteristics disturbed with the typical intracavity aberration in a folded unstable resonator with asymmetric circular mirrors firstly, then the corresponding subtle wavefront aberration is achieved by polynomial fitting with first

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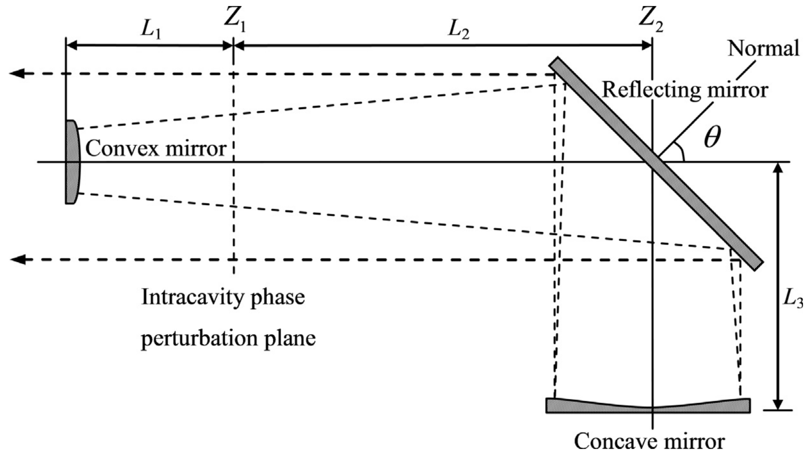

Fig. 1. Schematic diagram for asymmetric folded unstable resonators with intracavity phase perturbation.

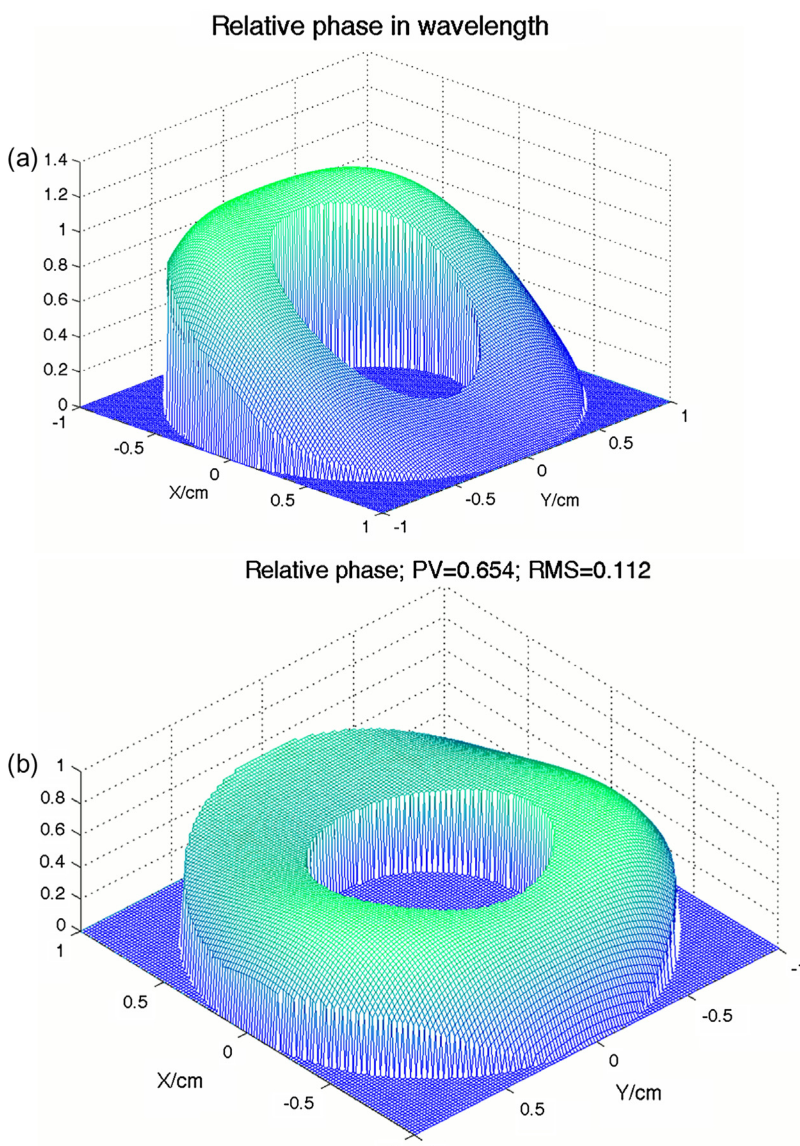

Fig. 2. Wavefront profiles with λ/8 intracavity tilt perturbation. (a) 3-D profiles; PV = 1.037λ and RMS = 0.304λ; (b) wavefront residual error with PV = 0.654λ and RMS = 0.112λ. In this case, two directional Zernike tilt aberrations are removed.