CCIT Report #610

January 2007

Odd mode separation in concentric resonators with bi-prism like element

Yurij Parkhomenko, Boris Spektor and Joseph Shamir
Department of Electrical Engineering, Technion - Israel Institute of Technology,
Haifa 32000, Israel

ABSTRACT

New methods of laser metrology (interferometry and microscopy) based on applications of beams with special structures provide increased resolution and efficiency. To generate a beam with linear singularity (dark beam) we recently proposed a beam shaping method using a bi-prism-like element within the laser resonator. There we have studied resonators that are traditionally designed to oscillate on the fundamental mode designed within the range of configuration parameters, $0.5 \le G \le 1$.

In the present work we extend the approach and show that the choice of specific configurations, outside the above range of configuration parameters, can lead to much better results for our application. This is the case in particular for an approximately semi-concentric resonator (G ~ -1).The optimal dark beam is obtained for a bi-prism angle about twice that obtained for the earlier configurations. For this case the difference between the losses of the first odd mode and other modes is 0.12-0.15, which is adequate for oscillation on this mode in lasers with any type of active media.

Keywords: mode selection, beam shaping, dark beam, semi-concentric resonator, bi-prism.

1. INTRODUCTION

Laser beam shaping is a well-studied subject and is usually implemented by some optical system, external to the laser cavity. In most cases such an external system consists of one or more phase elements and diffractive optical elements[1,2]. The disadvantages of such a solution include limited light efficiency, optical noise and intricate alignment procedures. One approach to mitigate these disadvantages is to shape the laser beam by a dedicated design of the laser resonator[3,4]. Our specific interest here is the generation of laser beams with a line singularity employed for high-resolution optical metrology. In this application, generally termed as Singular Beam Microscopy, a laser beam structured by one or more singularities scans the object and the scattered light is analyzed to derive nanoscale information about the object[5-7].

In recent work[8,9] we have studied the possibilities of employing a Bi-Prism like Element (BPE) to replace one of the laser mirrors for constructing a cavity that will primarily support oscillation on the first odd mode, which contains the desired line singularity. In that work we have studied resonators that are traditionally used in lasers to generate the fundamental even mode. These lasers belong to a family that possesses effective configuration parameters, G, (see Eq. 1 below) within the range $0 \le G \le 1$ and we have demonstrate efficient ways to achieve the desired beam shape. The main purpose of the present paper is to demonstrate that using resonators outside this family can lead to even better solutions for obtaining our desired beam structure. We show that resonators with $-1.2 \le G \le 0$ in combination with a BPE are extremely effective in oscillating on the first odd mode. Focusing on the neighborhood of the semi-concentric configuration we show that the intracavity BPE implements a physical process similar to splitting the resonator into two separate partial resonators with strong diffraction coupling.

In the following section we review relations and methods used for the numerical study. In Sec. 3 we present a numerical study to demonstrate the advantages of using resonators from the extended regime of configuration parameters and a concluding section completes the paper.