The conjugate source position and thermal stability of unstable resonator

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Abstract: *It is shown analytically that the thermal-stable condition for the conjugate source position of unstable resonators can not be satisfied.*

共轭点源位置与非稳腔的热稳定性

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摘要: 本文严格证明了非稳腔的共轭点源位置不可能实现热稳。

Introduction

It has been found that, in applications of unstable high power resonant cavities, the focus location flactuates with temperature variation[1]. Therefore, there is an urgent need to develop an unstable cavity in which the focus location is thermally-insensitive. Through detailed analysis of unstable cavities, we consider that if the conjugate source position does not shift with the thermal focal length, i. e. $dr/dt=0$ (r is the conjugate source position; f is the thermal focal length.), it can be achieved that the focus location does not shift. Because the focusing characteristics of spherical waves are only related to the curvatures of their wave fronts, and the curvature of the wave front in any position from a point source is equal to the distance from the location to the point source, we define

$$dr/dt = 0 \tag{1}$$

as an unstable cavity in which the focus location is thermally-insensitive.

For other unstable thermally-insensitive cavities, refer to[2,3].

Thermally-insensitive conditions of the focus location unshifting

As shown in Fig., radius of curvature of cavity mirror is separately R_1, R_2.

The laser matter is equivalent to a thin len which has variable thermal focal length f. The intracavity transformation matrix of both sides of the thermal focus is separately showed $\begin{pmatrix} A_1 & B_1 \\ C_1 & D_2 \end{pmatrix}$ and $\begin{pmatrix} A_2 & B_2 \\ C_2 & D_2 \end{pmatrix}$. The intracavity single pass transformation matrix is:

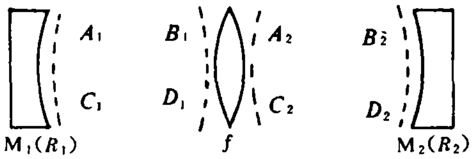

Fig. Multielement resonator containing the thermal lens

$$\begin{pmatrix} a & b \\ c & d \end{pmatrix} = \begin{pmatrix} A_2 & B_2 \\ C_2 & D_2 \end{pmatrix} \begin{bmatrix} 1 & 0 \\ -\frac{1}{f} & 1 \end{bmatrix} \begin{pmatrix} A_3 & B_3 \\ C_3 & D_3 \end{pmatrix} \tag{2}$$

The trip matrix in the multielement resonator containing the thermal lens:

$$\begin{pmatrix} A & B \\ C & D \end{pmatrix} = \begin{bmatrix} 1 & 0 \\ -\frac{2}{R_1} & 1 \end{bmatrix} \cdot \begin{pmatrix} d & b \\ c & a \end{pmatrix} \begin{bmatrix} 1 & 0 \\ -\frac{2}{R_2} & 1 \end{bmatrix} \begin{pmatrix} a & b \\ c & d \end{pmatrix} \tag{3}$$

According to the self reproduceable condition of the conjugate source position in an unstable resonator, we have

$$r = \frac{Ar + B}{Cr + D} \tag{4}$$

Solving (4), we obtain

$$\frac{1}{r} = \frac{D - A}{2B} \pm \frac{1}{B}\sqrt{\left(\frac{A + D}{2}\right)^2 - 1} \tag{5}$$

Because

$$\frac{D - A}{2B} = \frac{1}{P_1} = \frac{1}{R_1} \tag{6}$$

i. e.

$$\frac{\mathrm{d}\left(\frac{D - A}{2B}\right)}{\mathrm{d}f} = 0 \tag{7}$$

according the thermally-stable condition defined by us, we can obtain

$$\frac{\mathrm{d}\left(\frac{1}{r_1}\right)}{\mathrm{d}f} = \pm \frac{\mathrm{d}}{\mathrm{d}f}\left[\frac{1}{B}\sqrt{\left(\frac{A + D}{2}\right)^2 - 1}\right] = 0 \tag{8}$$

From (8), we can find the thermally-stable condition of the conjugate source position, but can find it by using a simpler method. Comparing formula (8) with the analysis of thermal stability in a stable resonator in the literature[4], we can know that, on the premise defined by formula (1), the thermally-stable condition in the unstable resonator is totally same as that in the stable resonator. That is, the thermally-stable condition of the conjugate source position unshifting is

$$\frac{1}{G_2} = 2G_2 + 2\left(\frac{B_1}{B_2}\right) + \frac{1}{G_2}\left(\frac{B_1}{B_2}\right)^2 \tag{9}$$

Limitation to the thermally-stable condition

Through arrangement of formula (9), we can obtain

$$G_1 = \frac{G_2}{G_2^{\,2} + (G_2 + k)^2} \qquad (k = \frac{B_1}{B_2}) \tag{10}$$

therefore

$$G_1 \cdot G_2 = \frac{G_2^{\,2}}{G_2^{\,2} + (G_2 + k)^2} \tag{11}$$

Because of $\quad G_2^{\,2} \geqslant 0 \qquad (G_2 + k)^2 \geqslant 0$

under the thermally-stable condition, there is

$$0 < G_1 \cdot G_2 < 1 \tag{12}$$

It is obvious that formula (12) is the confined stable condition of the resonant cavity. Therefore, all resonators meeting the thermally-stable condition given by formula (9) are stable resonators, and on the premise defined by formula (1), an unstable resonator can't achieve thermally-stable.

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[1] Reng N, Eppich B. Opt & Quant Electron, 1992; 24(9): 973～992

[2] Sun Nianchun, Deng Chongjun, Cheng jie *et al*. Laser Technology, 1992; 16(5): 298～301

[3] Lü Beida. Chinese Journal of Quantum Electronics, 1990; 7(2): 136～145

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·简　　讯·

《激光技术》已进入国外光盘数据库

根据同济大学副教授胡德敬先生提供的信息,本刊1992年第16卷第6期第349～353页发表的"透射体积全息图成象的几何分析"一文,已收录入美国《工程索引(Ei)》的光盘数据库(通过微机检索的打印件如后)。

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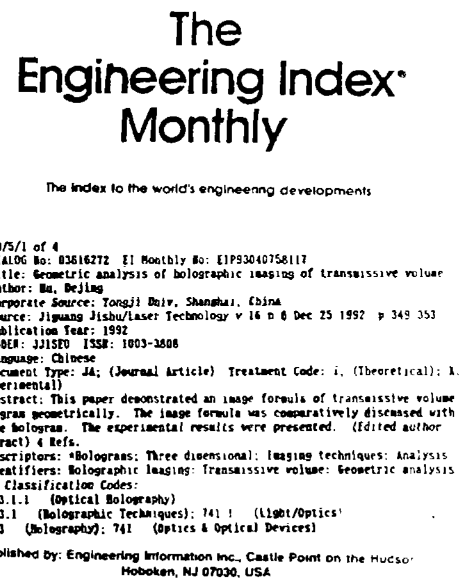

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