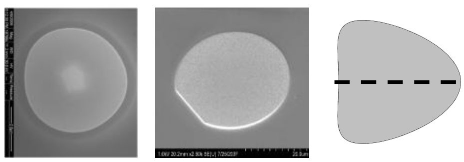
ACCURATE MODELING OF MICROCAVITY LASERS WITH SYMMETRY LINES BASED ON MULLER'S INTEGRAL EQUATIONS

Microcavities with a symmetry line (depart from a circle but not too far):

✓To keep low thresholds
✓To improve directionality

limaçon cut disk kite



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Lasing Eigenavlue problem

in 2-D: $U = E_z$ or H_z, $U \neq 0$ $\sim e^{-i\omega t}$

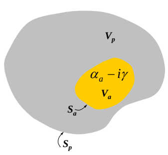
- Helmholtz equation off the boundaries

$$\left(\Delta + k^2\nu^2\right)U(r,\varphi) = 0$$

$$\sqrt{\varepsilon} = \nu = \alpha_{eff} - i\gamma$$

α_{eff} is effective refractive index

γ is threshold material gain



- Boundary conditions
- Sommerfeld radiation condition at infinity

The real-valued (κ_j, γ_j) are the eigenparameters

The Muller Integral Equations

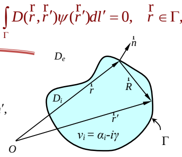
MIEs: $$\varphi(\vec r) + \int_\Gamma A(\vec r, \vec r')\varphi(\vec r')dl' - \int_\Gamma B(\vec r, \vec r')\psi(\vec r')dl' = 0,$$

$$(\eta_i + \eta_e)\psi(\vec r)/2\eta_e + \int_\Gamma C(\vec r, \vec r')\varphi(\vec r')dl' - \int_\Gamma D(\vec r, \vec r')\psi(\vec r')dl' = 0, \quad \vec r \in \Gamma,$$

Kernels:

$$A(\vec r, \vec r') = \partial G_i(\vec r, \vec r')/\partial n' - \partial G_e(\vec r, \vec r')/\partial n',$$
$$B(\vec r, \vec r') = G_i(\vec r, \vec r') - \eta_i/\eta_e G_e(\vec r, \vec r')$$
$$C(\vec r, \vec r') = \partial^2 G_i(\vec r, \vec r')/\partial n \partial n' - \partial^2 G_e(\vec r, \vec r')/\partial n \partial n',$$
$$D(\vec r, \vec r') = \partial G_i(\vec r, \vec r')/\partial n - \eta_i/\eta_e \partial G_e(\vec r, \vec r')/\partial n$$

Green's function: $G_j(\vec r, \vec r') = \frac{i}{4}H_0^{(1)}(k_j R)$



- Integration over a closed contour
- Fredholm 2-nd kind equations
- Equivalency to original problem: no spurious eigenvalues

Discretization of IEs

Extraction of logarithmic part from kernels:

$$F(t,\tau) = F_1(t,\tau)\ln[4\sin^2((t-\tau)/2)] + F_2(t,\tau), \quad F = A, B, C, D,$$

For the logarithmic parts use the quadrature with trigonometric polynomials:

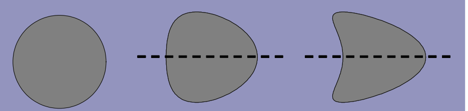
$$\int_0^{2\pi} \ln[4\sin^2((t-\tau)/2)]F_1(t,\tau)f(\tau)L(\tau)d\tau = \sum_{p=0}^{2N-1} P_p^{(N)}(t)F_1(t,t_p)f(t_p)L(t_p)$$

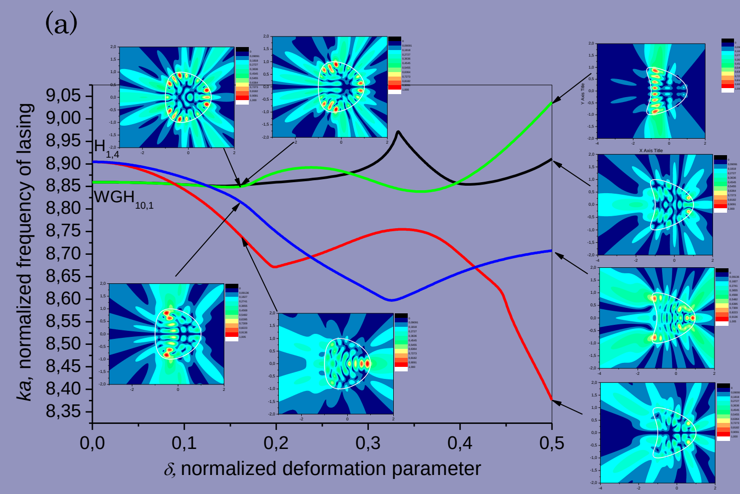
$$P_p^{(N)}(t) = -(2\pi/N)\sum_{m=1}^{N-1}\cos\left[m(t-t_p)\right]/m - \pi\cos\left[N(t-t_p)\right]/N^2$$

For regular parts use trapezoid formula:

$$\int_0^{2\pi} F_2(\vec r, \vec r')f(\vec r')dl' = (\pi/N)\sum_{p=0}^{2N-1} F_2(t,t_p)f(t_p)L(t_p)$$

$$x(t) = a(\cos t + \delta\cos 2t - \delta),$$
$$y(t) = a\sin t$$





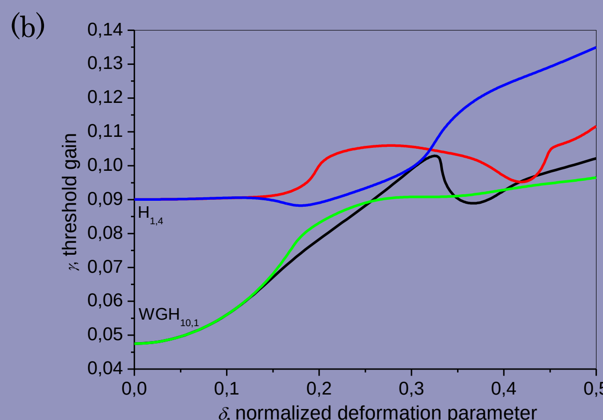


Fig. 1. Dependences of lasing frequencies (a) and threshold gains (b) on normalized deformation parameter for doublets of modes $WGH_{10,1}$ (black and green lines) and $H_{1,4}$.(blue and red lines). Inserts are modal field patterns at corresponding values of marked by arrows. Other parameters: N = 50, =1.5.

Conclusions

➢By deforming the disk into a kite resonator one splits the modes into doublets of even and odd modes
➢The directivity of emission of the modes increases however at the expense of higher thresholds
➢ WG modes keep their favorable features in a convex kite

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