Absorption Induced Confinement of Lasing Modes in Diffusive Random Medium

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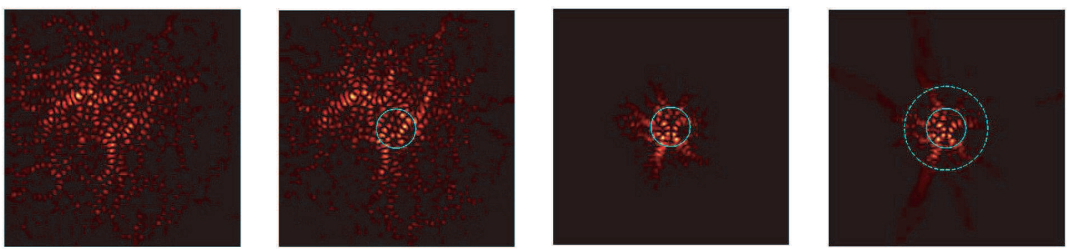
Tight focusing of pump light on a weakly scatting (diffusive) random medium can lead to lasing with coherent feedback [1]. Imaging of laser light on the sample surface revealed that the lasing modes were not extended over the entire random medium, instead they were located inside the pumped region with an exponential tail outside of it [2]. Since the quasimodes of a random system far from the onset of localization are usually extended states, the origin of the localized lasing modes is not clear.

We use FDTD method to simulate lasing in TM modes of 2D random media. The disordered system is a collection of dielectric cylinders placed at random in vacuum. The lateral dimension of 2D random system is $9.2\,\mu$m. Transport mean free path $l \simeq 1.3\,\mu\text{m} \ll L$, so that the system is in the diffusive regime. By assigning negative conductance (inside cylinders) to the pumped region and positive conductance to unpumped region, we are able to include both light amplification and reabsorption of the emitted light.



(a) (b) (c) (d)

Figure 1: Mode modification in the presence of reabsorption (see text).

Fig. 1(a) shows spatial intensity distribution of the (extended) quasimode with the longest lifetime in a passive diffusive system. in Fig. 1(b) we show the (first) lasing mode with gain inside the circular region near the center and no absorption outside. Although optical gain is local, the lasing mode is extended throughout the entire sample-the lasing mode profile remains the same as in Fig. 1(a). The lasing mode in the presence of reabsorption outside the circle, Fig. 1(c), is a new mode, completely different from the quasimode of the passive system. It is confined inside the pumped region, and shows an exponential decay outside. The reabsorption suppresses the feedback from absorbing part of the sample, effectively reducing the system size to V_{eff}. Indeed, Fig. 1(d) depicts the lasing mode when we remove all the random medium beyond one diffusive absorption length from the pump area (dashed circle). The frequency and spatial profile of the lasing mode remain the same as in Fig. 1(c).

This reduction of the effective system volume leads to a decrease of the Thouless number $\delta \equiv \delta\nu/\Delta\nu$, where $\delta\nu$ and $\Delta\nu$ are the average mode linewidth and spacing respectively. In a 3D diffusive system $\delta\nu \propto V_{eff}^{-2/3}$ and $\delta\nu \propto V_{eff}^{-1}$, therefore, $\delta \propto V_{eff}^{1/3}$. The smaller the value of δ, the larger the fluctuation of the decay rates γ of the quasimodes. We believe the broadening of the decay rate distribution along with the decrease of the total number of quasimodes (within V_{eff}) is responsible for the observation of discrete lasing peaks in the regime of tight focusing of pump beam [1].

REFERENCES

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