Stimulated scattering in supermode microcavities: Single- or dual-mode lasing?

June 1 2021, by Huang Weijian

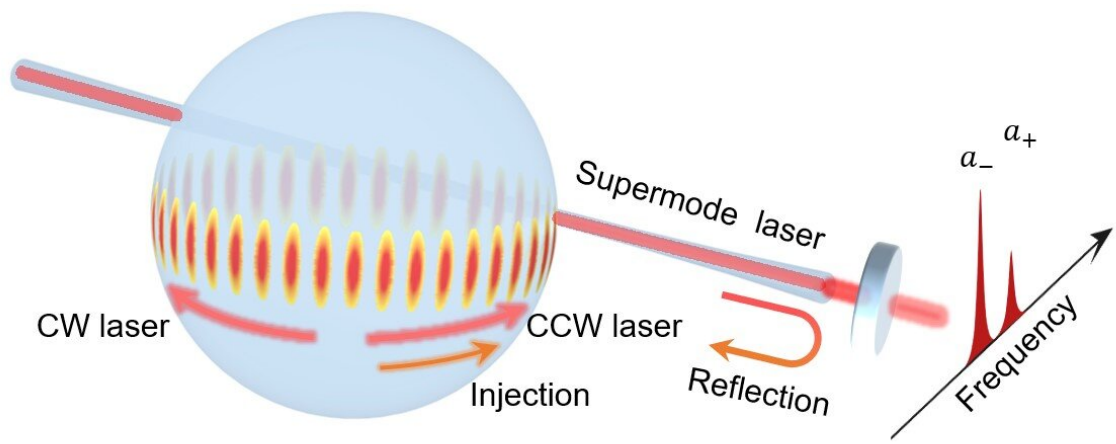

Fig.1 Generation and manipulation of supermode Raman laser in a microcavity. Credit: Peking University

Stimulated scattering in supermode microcavities, such as Raman or Brillouin lasers, has shown unprecedented merit for precision measurements by exploiting the beat note in their lasing spectra. This beat note corresponds to the energy splitting of supermodes and is highly sensitive to any external perturbations. However, a pivotal question has puzzled the researchers for two decades: are these supermode microcavity lasers single or dual modes? Now, a research team led by Professor Xiao Yunfeng at Peking University has revealed the lasing dynamics of a stimulated scattering laser in a supermode microcavity, and experimentally demonstrated its single-mode nature. This work has been published online in *PNAS*.

The paradox arises from the contradiction between the laser theory and experimental observations. On the one hand, due to the homogeneous gain, the pump field should always be clamped after the laser emits, leading to a single-mode laser. On the other hand, however, the widely observed beat notes provided evidences for dual-mode lasing. "This beating phenomenon really contradicts what we have learnt from the textbook, but it does exist," said Cao Qitao, a Boya postdoctoral researcher at Peking university, "so we think there must be some physics hidden." The researchers used surface scattering to construct a pair of supermodes in a whispering-gallery microcavity (Fig.1), and generated an ultralow-threshold Raman laser. Then, they adopted an add-drop coupling structure to directly acquire the intracavity pump power, by which the clamping effect of the pump field is observed for the first time (Fig.2). Moreover, with the help of a heterodyne method, the measured side mode suppression ratio (SMSR) is characterized to be over 30 dB, so that the single-mode characteristic of the Raman laser in supermode microcavity is unambiguously demonstrated.

"To reveal the underlying physics of the previously observed beating phenomenon, we utilized the self-injection method to modulate the mode losses of the two supermodes," said Zhang Peiji, a Ph.D. student at Peking University. Experimentally, self-injection was introduced by a weak reflectance on the output laser, and part of the output laser is injected back into cavity to interfere with the intracavity laser field. With the self-injection method, the previously observed periodic beating phenomenon emerged in the time domain (Fig.2). Further theoretical analysis reveals that the previously reported beatnote arises from the transient interference during the switching process between the supermode lasers, rather than the simultaneous lasing of the two supermodes. Application-wise, this self-injection method may contribute to the selective generation of near-degenerate lasers and the improvement of their SMSR.

"Our results have clearly elucidated the long-existing debate on the lasing spectrum paradox of stimulated scattering in supermode microcavities," said Professor Xiao. "Besides, this work provides an insightful guidance for microlaser-based precision measurements and paves the way to reconfigurable light sources and low-power-consumption optical memories."

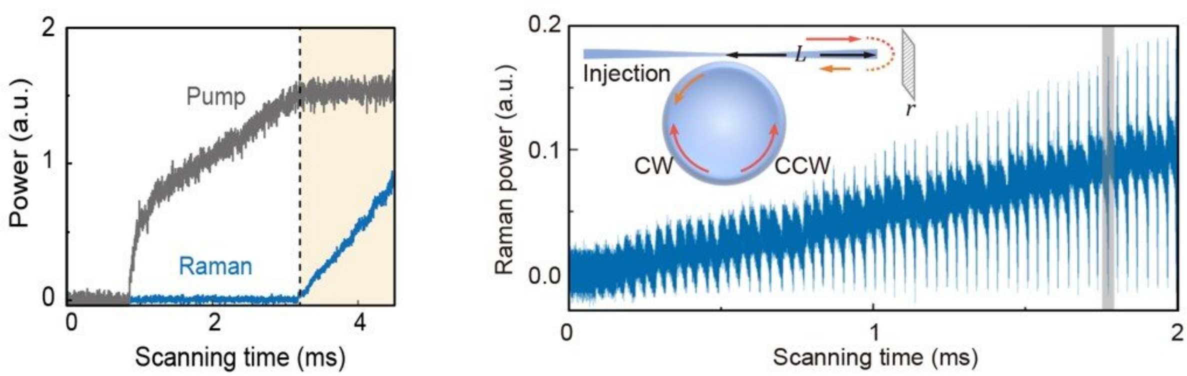

Fig.2 Left: clamping effect of the pump field. Right: beating phenomenon of output Raman laser with self-injection in time domain. Credit: Peking University

More information: Pei-Ji Zhang et al, Single-mode characteristic of a supermode microcavity Raman laser, *Proceedings of the National Academy of Sciences* (2021). DOI: 10.1073/pnas.2101605118

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