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k-space theory of stimulated Raman and Brillouin side scattering

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Side scattering, in contrast to backscattering, is a stimulated scattering process where the scattered light is perpendicular to the density or flow velocity gradient. It includes stimulated Raman side scattering (SRSS) and stimulated Brillouin side scattering (SBSS), where a pump laser is scattered by Langmuir wave and ion acoustic wave, respectively.

Recent ignition-scaled experiments have observed SRSS and attracted a renewed interest on the excitation of side scatters in inertial confinement fusion (ICF). These experiments involve a variety of parameter spaces, such as those on the national ignition facility (NIF), OMEGA laser facility, LULI, and SGII laser facility [1-3], implying a robust existence of side scattering in ICF.

However, the inherent complexity of side scattering is much greater than the backscattering, which is not fully understood. Previous theories were mostly based on the analyses of real space (x-space) equations and path integral method [4-6]. There are also some incorrect formulas and ambiguous physics in those old references, for example the absolute threshold of SBSS was not correct, and the convective gains of side scatterings are still very unclear.

To settle these problems and better understand the behavior of side scattering in the linear stage, we have developed a k-space (or Fourier space) theory for both stimulated Raman and Brillouin side scattering [7]. The linear physics of side scattering can be described by a general Schrodinger equation with a quartic potential in k space. It shows intrinsic differences with backscattering. This Schrodinger equation is analytically solved through WKBJ method, and its eigenvalue reveals an absolute nature of side scattering. Therefore, we obtained absolute thresholds for both Raman and Brillouin side scatterings, and analytic formulas of convective gains when the threshold is not surpassed. Effect of finite beam width on side scattering has also been discussed. Using this theory, we can explain the recent side scattering experiments and reassessed the significance of side scatterings under conditions relevant to the ignition scale.

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