Theory of stimulated scattering and harmonics in homogeneous and inhomogeneous laser plasmas

Tan Weihan *Wang Runwen* *Ding Liming*

(Shanghai Institute of Optics and Fine Mechanics, Academia Sinica)

The problem of coupling laser energy to plasmas to produce efficient compression in laser nuclear fusion has so far been a subject of great interest. Apart from resonance absorption and anomalous absorption, the stimulated scattering of incident laser light in the under-density plasmas of corona is also an important problem to deal with, because it has a great influence on the laser energy for heating the plasmas. The main results of this paper are:

1) We obtain from Vlasov equation the general equations for the electrons, ions of homogeneous and inhomogeneous plasmas and electromagnetic radiation.
2) Having solved these equations, the threshold powers and the growth rates of the stimulated Brillouin, Raman scattering and harmonic generation in unbound homogeneous and unbound inhomogeneous plasmas are obtained.
3) In the case of bound inhomogeneous plasmas, the stimulated Brillouin scattering, which influences greatly the absorption of laser energy by plasmas, is analysed. And the scale equation which describes the relation between the growth rate ν and the characteristic length L is also obtained: $P+\nu=1.19\sqrt{\frac{\gamma\cdot V}{L}}$ (p-spatial gain, γ-pumping power, V-group velocity of the scattering waves)
4) Having analysed the results of the coupling equations and the data of the harmonics experiments described in literature, we propose a successive-generating mechanism of the harmonics and sub-harmonics (semi-integer harmonic). Firstly, there are strong Langmuir waves near the critical surface owing to resonance absorption. The beat between the Langmuir waves and the incident waves $E\omega_0$ generate $E_2\omega_0$ waves. And the beat between the Langmuir waves and $E_2\omega_0$ generates $E_3\omega_0$. Similarly, series of harmonics of still higher orders can be generated successively. The subharmonics are caused by the beat between the incident waves and two $\frac{\omega_0}{2}$ Langmuir waves, which arise from the parameter decay in the ¼ critical surface. So the ratio between the amplitudes of two neighbouring harmonics is almost a constant:

$$E_{j+1}/E_j=-\omega_p{}^2 n_e/[\omega_0(-\omega^2+i\nu_e+\omega_{el}{}^2)]$$

This result is in agreement with the relevant experiments.

均匀与非均匀等离子体中的受激散射与谐波理论

谭维翰　王润文　丁丽明

激光核聚变中，激光能量耦合到等离子体中来产生有效的压缩是当前被关心的问题，除反常吸收与共振吸收外，弄清楚在冕区稀密度等离子体中对入射激光的受激散射是个重要的问题。因为它直接阻止激光能量进入临界面，降低了激光加热的有效性。本文主要结果有：

①从 Vlasov 方程出发，导得了适用均匀与非均匀等离子体的电子、离子与电磁辐射的耦合方程组。

②解这组方程求得了无界均匀与非均匀等离子体的受激布里渊及受激喇曼散射与谐波产生的阈值功率与增率表式。

③在有界非均匀等离子体情况下分析了对激光吸收带来严重影响的布里渊散射，求得了增率 ν 与特征长度 L 等的定标关系：$P+\nu=1.19\sqrt{\frac{\gamma\cdot V}{L}}$（$P$—空间增益，$\gamma$—泵浦功率，$V$—散射波群速度）。

④从分析耦合方程的理论结果与文献上有关谐波的实验数据，提出了谐波与次谐波（半整数）的逐级产生机制。首先由于共振吸收在临界密度处产生强的 Langmuir 波，它与入射波 $E\omega_0$ 差拍产生 $E_2\omega_0$ 波，$E_2\omega_0$ 在 Langmuir 波上再散射一次便得 $E_3\omega_0$ 波，依次推得各高次谐波的产生。而次谐波系列认为是在¼临界面上参量衰变出现的两个 $\frac{\omega_0}{2}$ Langmuir 波与入射波逐次和频差频而产生的，于是导得各波谐波振幅比是一常数的结论：

$$E_{j+1}/E_j=-\omega_p{}^2 n_e/[\omega_0(-\omega^2+i\nu_e+\omega_{el}{}^2)]$$

左边函数与谐波频率无关，这与已报导的实验结果相符。