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Thesis: Autoresonance in three-wave interactions with bandwidth

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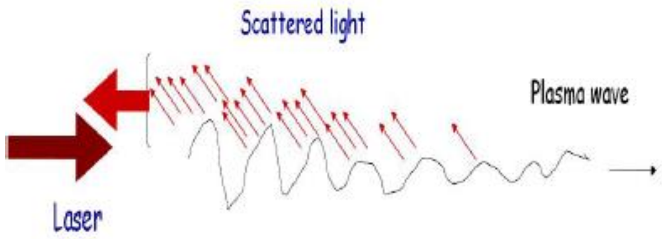
3-wave coupling：

describing stimulated scattering processes : **2 EM waves with 1 plasma wave**， by matching their frequencies. and wave vectors for resonance, **w_0 = w_1 + w_2 and k_0 = k_1 + k_2**

Such models can help to **understand instabilities in laser fusion**.

And they can describe how **to amplify short laser pulses with the help of plasma waves.**

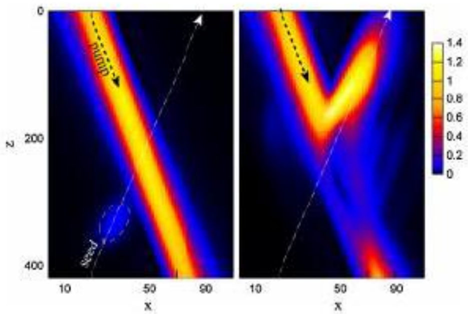


3-wave coupling equations

$$(\partial_t + c_0\partial_z)a_0 = -\Gamma_0 a_1 a_{L/S}$$ (Laser light pump envelope)

$$(\partial_t - c_1\partial_z)a_1 = +\Gamma_1 a_0 a_{L/S}^*$$ (Backscattered light envelope)

$$(\partial_t + c_{L/S}\partial_z)a_{L/S} = +\Gamma_{L/S} a_0 a_1^*$$ (Plasma wave envelope)



L : Fast electron responde

S : Slow Ion responde

Autoresonance can appear via the combination of **nonlinearities of plasma waves** and detuning of the 3-wave resonance **due to inhomogeneity**. One may compensate the other so that resonance is maintained.

$$(\partial_t + c_{L/S}\partial_z - i\delta\omega + ic_{L/S}\kappa' z)a_{L/S} = +\Gamma_{L/S} a_0 a_1^*$$

Due to nonlinearities **Due to inhomogeneity**

Nonlinearities can come from **kinetic effects** (particles trapped in the wave's potential), **relativistic effects,higher wave harmonics**, but each with different consequences

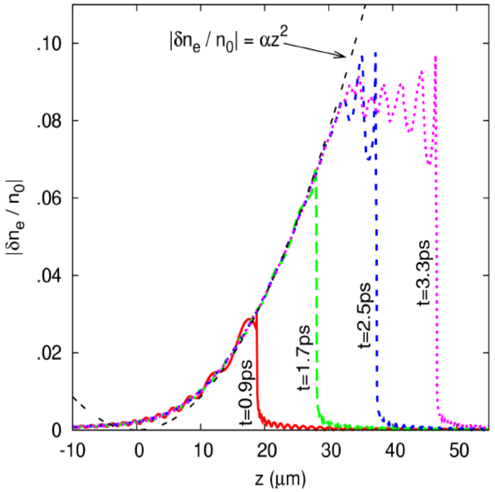
eg. For particles trapped: $\delta\omega = \eta\omega_{L/S}|a_{L/S}|^{1/2}$

For higher wave harmonics: $\delta\omega = -\beta|a_{L/S}|^2$

Thomas D.Chapman's work: **Autoresonance between electrons trapped and inhomogeneity inSRS**

$$\left(\frac{\partial}{\partial t} + c_L\frac{\partial}{\partial z} - i\eta\omega_L|a_L|^{1/2} + i c_L\kappa' z\right)a_L = P(t)$$

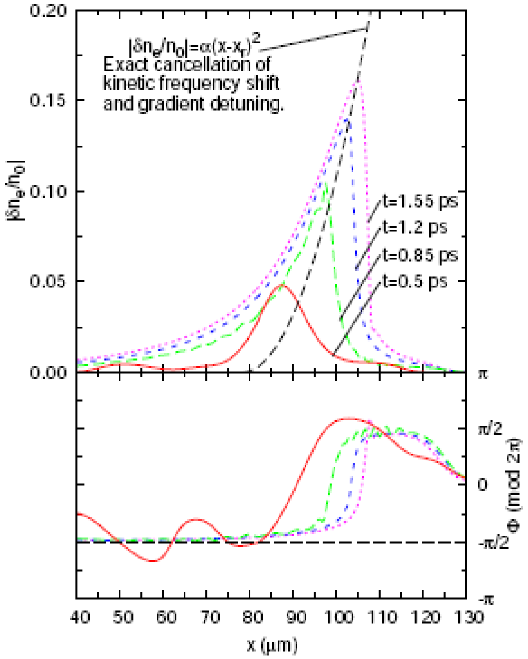
cancellation of shift
→ parabolic growth



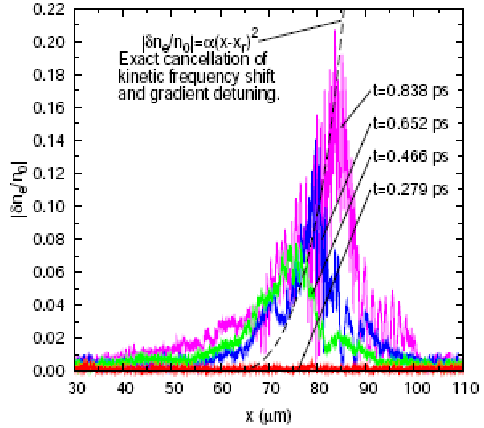
- Langmuir wave propagates from 3-wave resonance point at group velocity.
- Langmuir wave is phase locked to the ponderomotive drive and grows along a parabola as it propagates.
- Under certain conditions, growth can be far greater than the level reached at Rosenbluth saturation.
- Autoresonance lost at

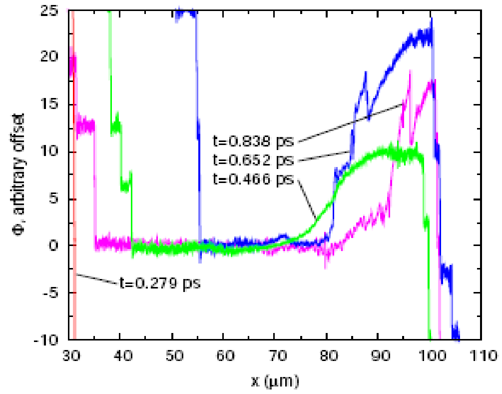
$$\frac{\delta n_e}{n_0} = 9\%$$

3-wave coupling model



PIC simulations





On Chapman's work, The pump light is monochromatic ,we **want to put bandwidth Δω to pump.**

The bandwidth will come from random phase of pump:

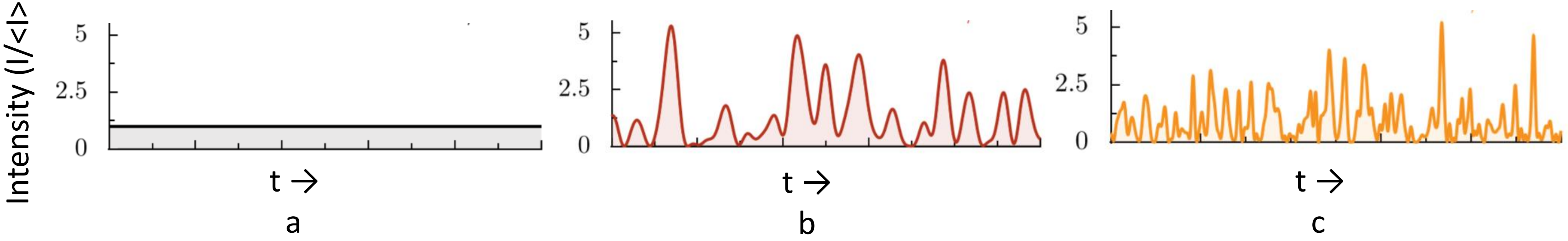
$S(\tau)$=exp[i$\varphi(\tau)$]

$\varphi(\tau)$ is the $ramdom\ phase\ of\ the\ pump$ uniformly distributed in the interval [0,2π], and the time τ form a Possion process with mean rate $\Delta\omega$.

The correlation function

$\phi(\tau)$=⟨$exp\{i[\varphi(t+\tau)-\varphi(t)]\}$⟩=exp(−$\Delta\omega|\tau|$)

0= $\Delta\omega$(a) <$\Delta\omega$(b)<$\Delta\omega$(c)



Under the assumption of bandwidth of pump:

$\Delta\omega$ will reduce the growth rate of plasma wave and scattered light,but will broadens the region of interaction in inhomogeneous plasma.

We can also expect to get **the cancellation of shift and phase locked** during autoresonance .

But:

A exact resonance region not just a point.

The autoresonance curve could be different.