Inflationary stimulated Raman scattering driven by a broadband laser in shock-ignition

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The problem: inflationary SRS in shock-ignition

- In shock-ignition, when the high-intensity “spike” of the laser pulse is reached, the plasma is **hot** and has **long density scale-length**.
- Both sub-scale [*Riconda et al. 2011; Cristoforetti et al. 2017*] and full-scale [*Rosenberg et al. 2020; Baton et al. 2020*] shock-ignition experiments on various laser facilities have measured SRS from densities where $k_{\mathbf{EPW}}\lambda_D \geq 0.25$.
- Inflationary SRS could lead to **significant reflection** of laser light and production of deleterious **hot electrons**.

Result

In our previous work [*Spencer et al. n.d.*], we used PIC simulations to show that iSRS can occur, via autoresonance [*Chapman et al. 2010*], in shock- ignition plasmas.

Potential solution: broadband laser driver

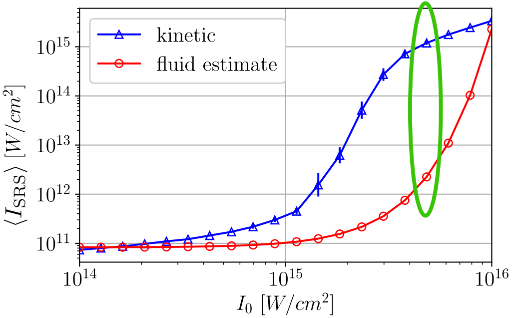
Zhao et al. 2019 used a Rosenbluth-like analysis to show that parametric instabilities in inhomogeneous plasmas can be controlled at low levels when driven by a **decoupled broadband laser (DBL)** satisfying certain conditions on $\delta\omega_0$.

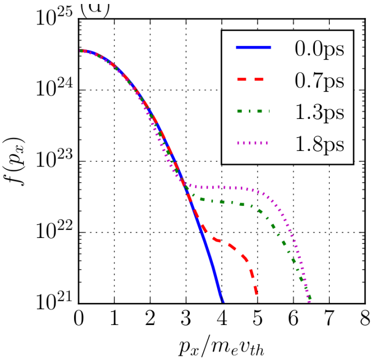
In this work, we seek to show that such a **DBL can suppress iSRS in shock-ignition plasmas** driven above the iSRS threshold intensity.

Defining the laser driver

We construct our broadband driver by considering N beamlets with different frequencies ω_i such that: $a = \sum_{i=1}^{N} a_i \sin(\omega_i t + \phi_i)$

With zero bandwidth, inflationary SRS can be important in shock-ignition plasmas

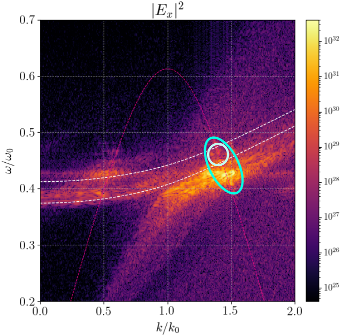




Result

iSRS is characterised by: an intensity threshold; trapping in EPWs; non-linear frequency shift; growth of beam acoustic modes.

Bandwidth chosen from fluid theory ($\Delta\omega_0 = 4\%\omega_0$, $N = 3$) **is insufficient to suppress iSRS.**



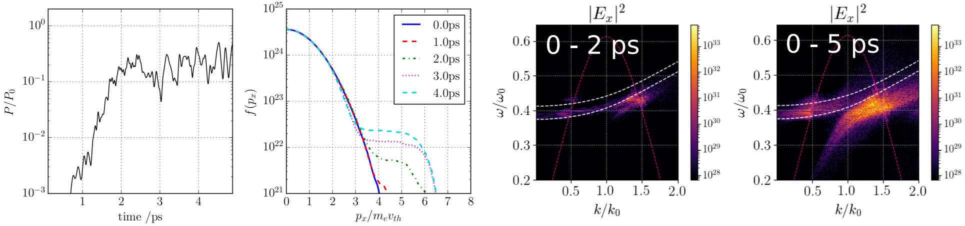
According to Zhao *et al.* Zhao et al. 2019, we would expect SRS and re-scatter of SRS light to both be suppressed by this bandwidth since:

$$\delta\omega_0 = \Delta\omega_0(N-1) > (\omega_{\mathrm{EPW2}} - \omega_{\mathrm{EPW1}})$$

Result

-Initial growth of iSRS is slower, no suppression once it gets going.
-Time-averaged power in SRS-reflected light is $21.5\% I_0$ (compared to 25.4% with no bandwidth.)

Bandwidth chosen from kinetic simulations ($\Delta\omega_0 = 12\%\omega_0$, $N = 3$) suppresses iSRS.



Result

- iSRS is initially strongly suppressed. For $t < 2$ps, time-averaged reflectivity $< 1\%$.
- Once a significant trapped particle population evolves, suppression is not maintained. Averaged over all time, reflectivity is 13% (cf. 25% with no bandwidth).

Conclusions

Caveat

These results are based on a small simulation study, with only one type of bandwidth applied.

- For a shock-ignition relevant plasma, driven above the iSRS threshold intensity, **significant bandwidth must be applied ($\sim 10\%$) in order to suppress iSRS.**
- The future direction of this campaign will be informed by the talks presented today, but we expect it will include:
  - Simulating a full SI density-profile in 1D, to understand re-scatter effects.
  - Understanding how bandwidth affects the iSRS threshold.
  - 2D PIC simulations, to understand the interaction of bandwidth with laser speckles.

References I

[1] S.D. Baton et al. In: *High Energy Density Physics* 36 (2020).

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[3] G. Cristoforetti et al. In: *Europhysics Letters* 117.3 (Feb. 2017), p. 35001.

[4] C. Riconda et al. In: *Physics of Plasmas* 18.9 (2011), p. 092701.

[5] M. J. Rosenberg et al. In: *Physics of Plasmas* 27.4 (2020), p. 042705.

[6] SJ Spencer et al. In: *In Review* ().

[7] Yao Zhao et al. In: *Plasma Physics and Controlled Fusion* 61.11 (Oct. 2019), p. 115008.

Thank you for listening! Any questions? [1]

[1] If you think of any afterwards, please contact me via `s-j.spencer@warwick.ac.uk`; or `https://sj-spencer.github.io/`

Backup slides

PIC simulation parameters

$\lambda_0 = 0.351\mu\text{m}$; $I_0 = 4.8 \times 10^{15}\text{W/cm}^2$; $T_e = 4.5\text{keV}$; $L_n = 500\mu\text{m}$; $n(x) = n_{\text{min}}\exp(x/L_n)$; $L_x = 100\mu\text{m}$; $k_{\text{EPW}}\lambda_D = [0.29, 0.35]$