A Model of Hot-Electron Signals with Overlapping Pump Beams

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Summary

- Experiments have shown an unusually strong variation of the hot electron signal with the number of overlapped beams.
- We propose a phenomenological model of explanation.
- The model also predicts the signal variation with energy in a single beam, and this is in accord with experiment
- The predicted effect of SSD or PS on the signal is in qualitative accord with the observations.

There are some intriguing aspects to the hard x-ray signals in certain OMEGA experiments

- At the 2001 Anomalous Absorption Conference, Stoeckl showed that these signals are clearly correlated with electrons arising from the two-plasmon instability.
- The original set of experiments, in spherical geometry, showed that the signal increased sharply with overlapped intensity (which varied with the target diameter).
- Later planar-foil experiments, using up to six interaction beams, clarified details of the variation.

Hard x rays and 3ω/2 signals correlate in time and intensity ($2\omega_p$ instability)

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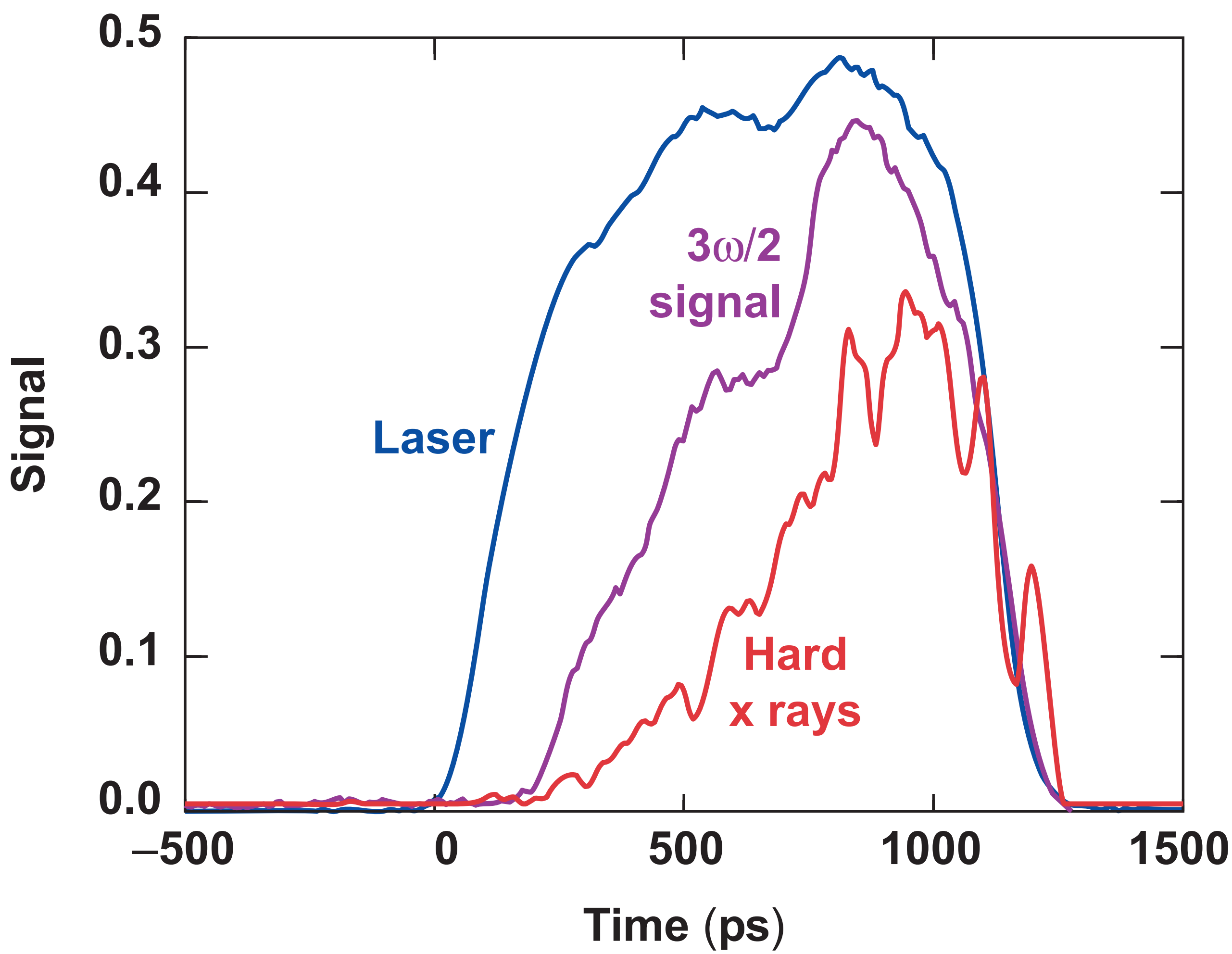

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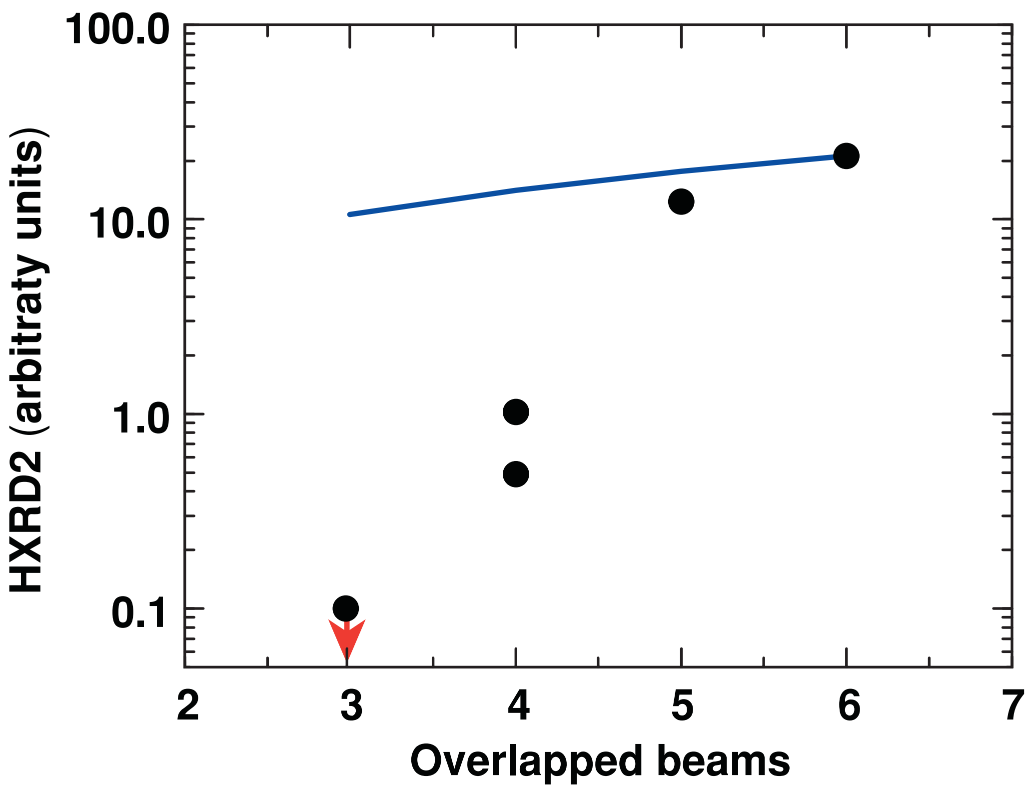
The hard x-ray signal increases exponentially with the number of overlapped beams

- The contrast between an expected linear variation with the number of beams and the measurements is striking.



- Simultaneous and coherent action of several lasers' electric fields, at quarter-critical, is one possible explanation but seems highly unlikely.

- Instead, we would like to propose a phenomenological model.

The model is based on a few assumptions

1. The signal is from hot electrons produced by the two-plasmon instability near quarter-critical. The single-beam signal may be represented in the form

$$S_1 = \alpha P_{noise} G,$$

where G is the gain in the two-plasmon wave power over the thermal level (P_{noise}) and α represents the conversion efficiency to x rays.

2. The gain is over a very brief time interval (in a hot spot or filament), owing to pump decorrelation induced by the dynamical plasma. A possible time interval is of the order of sub-picoseconds (Vu, LULI).

3. With two similar beams, the enhanced plasma-wave bundle enters, or is overlapped by, a feature in the second beam, and further growth occurs. The signal increases to

$$S_2 = \alpha P_{noise} G^2.$$

The model is based on a few assumptions (continued)

4. We assume no correlation between the two beams, as regards their initiation and development of the instability.

5. For N similar overlapped beams, each contributes in a statistical fashion. The resultant signal is

$$S_N = \alpha P_{\text{noise}} G^N;$$

$$\text{or } \ln S_N = N \ln G + \ell\text{n}\,(\alpha P_{\text{noise}}),$$

which fits the experimental results. Of course, the linear variation of $\ell\text{n}\, S_N$ with N must turn over when nonlinear effects limit further plasma-wave growth.

- A rough comparison with the data yields $G \cong 5$

Let us apply this model to experiments with reduced energy in the beams

- Stoeckl has compared different numbers of beams with reduced energy. He finds a common trend.
- For example, he finds that six beams at half-energy yield the same signal as three beams at full energy. Using our model, this requires

$$\alpha P_{\text{noise}} G_{\text{half}}^{6} = \alpha P_{\text{noise}} G_{\text{full}}^{3}$$

$$\text{or } G_{\text{half}} = G_{\text{full}}^{1/2}.$$

- Further, a similar equality is seen for equal divisions of the total energy among N-beams. This implies

$$\alpha P_{\text{noise}} (G_N)^N = \text{cst},$$

$$\text{where } N = \frac{E}{E_N}.$$

Let us apply this model to experiments with reduced energy in the beams (continued)

- Hence,

$$N \ln (G_N) = \text{cst.}$$

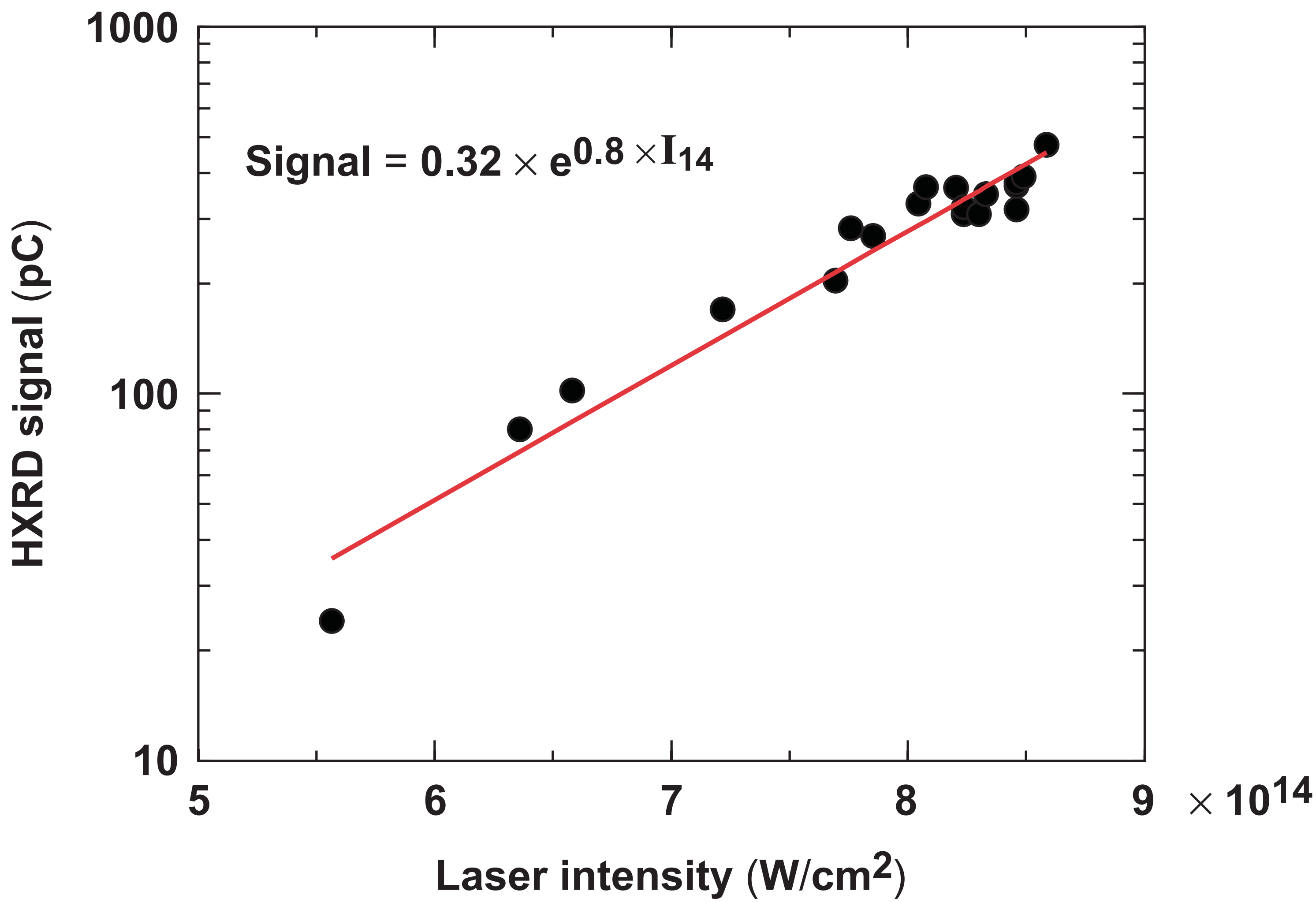
$$\underline{\text{or}} \quad \ln (G_N) = \beta E_N$$

$$\underline{\text{or}} \quad G_N \sim \exp (\beta E_N).$$

- This exponential dependence of the single-beam gain on energy has been verified by experiment.

The x-ray signal rises exponentially with laser intensity

- 20-μm shell, 1-mm-diam, 1-ns square



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Here are some comments on collisional effects, SSD, and polarization smoothing

- SSD would increase the probability of hot-spot features moving across the enhanced packet of waves; hence, the signal would increase with SSD.

- PS would mostly decrease the intensity in each hot spot, thus decreasing the signal.

- Both of these tendencies have been seen.

Improvements in the single-beam nonuniformity by SSD or PS affect the hard x-ray emission for spherical targets

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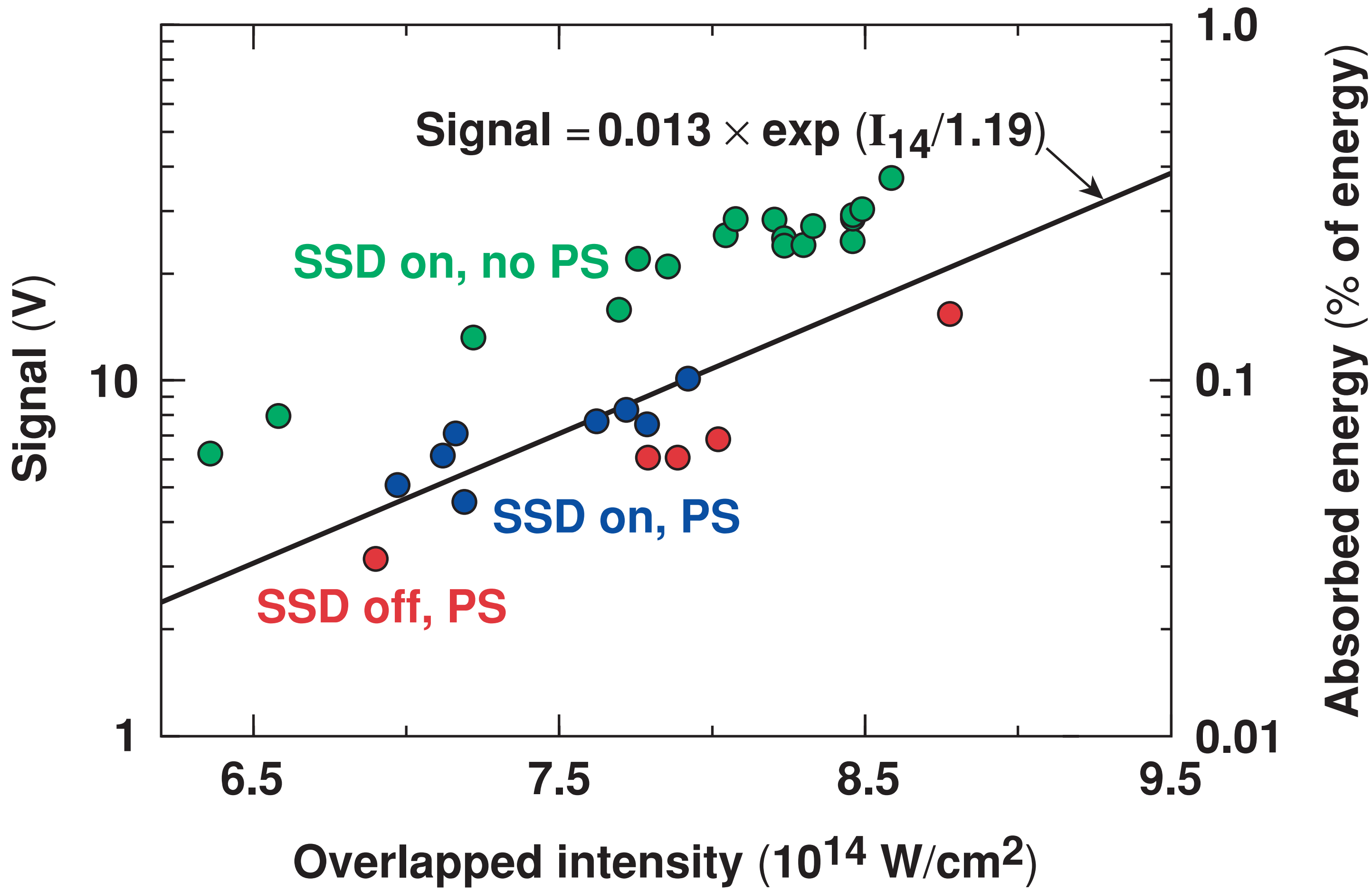
- CH shell, 950-μm diam., 1-ns square, varying single-beam intensity



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Summary/Conclusions

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