# Can We Really Control Stimulated Raman and Brillouin Backscattering by Superposing Large Amplitude Waves onto the Plasma an Making it an Inhospitable Environment for Their Growth?

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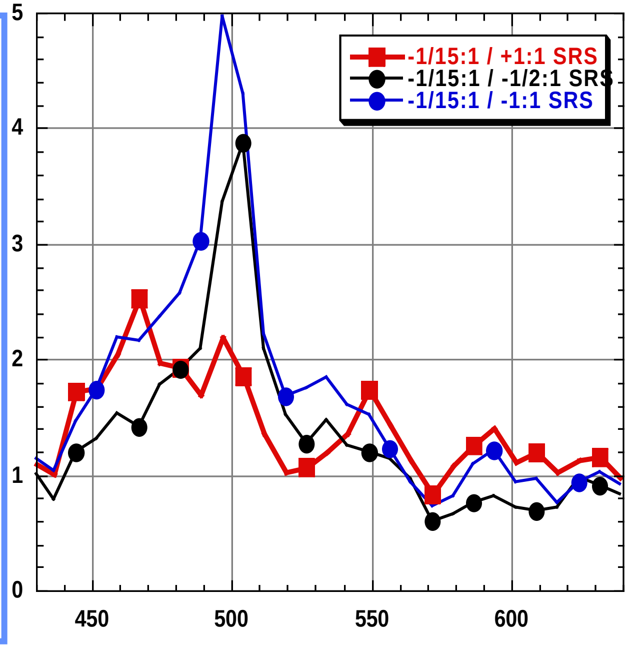
Reduction of SRS is strongly peaked in the 490-515 nm wavelength Range



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$\omega_{pe}^2 = \frac{4\pi n_e e^2}{m_e}$

$\frac{e^2}{\hbar c} \approx \frac{1}{137}$

**Presented at the SRS/SBS Saturation Workshop**
**Wente Vineyards**
**April 3-5, 2002**

# The Big Picture

- Can we devise externally controllable methods of rendering the plasma conditions there where laser beams have to traverse in hohlraums (~ cm range) or direct drive ICF targets (~mm range) inhospitable to excessive levels of parametric instability and unchecked growth, backscattering, hot $e^-$ generation, etc.?
- Could try and vary plasma density, temperature and velocity profiles by ab initio target fabrication and illumination condition designs (SSD, foam, PS). But this allows very little dynamical (run-time) control and have been shown to be weakly effective (< factor of 2).
- Alternative (or complementary) is to use optical mixing techniques, ie nonlinear optics technology to generate waves and disturbances which can do the job. How well? That is the subject of this study!

# The Overall Program or Vision for OMC SSI Experiments

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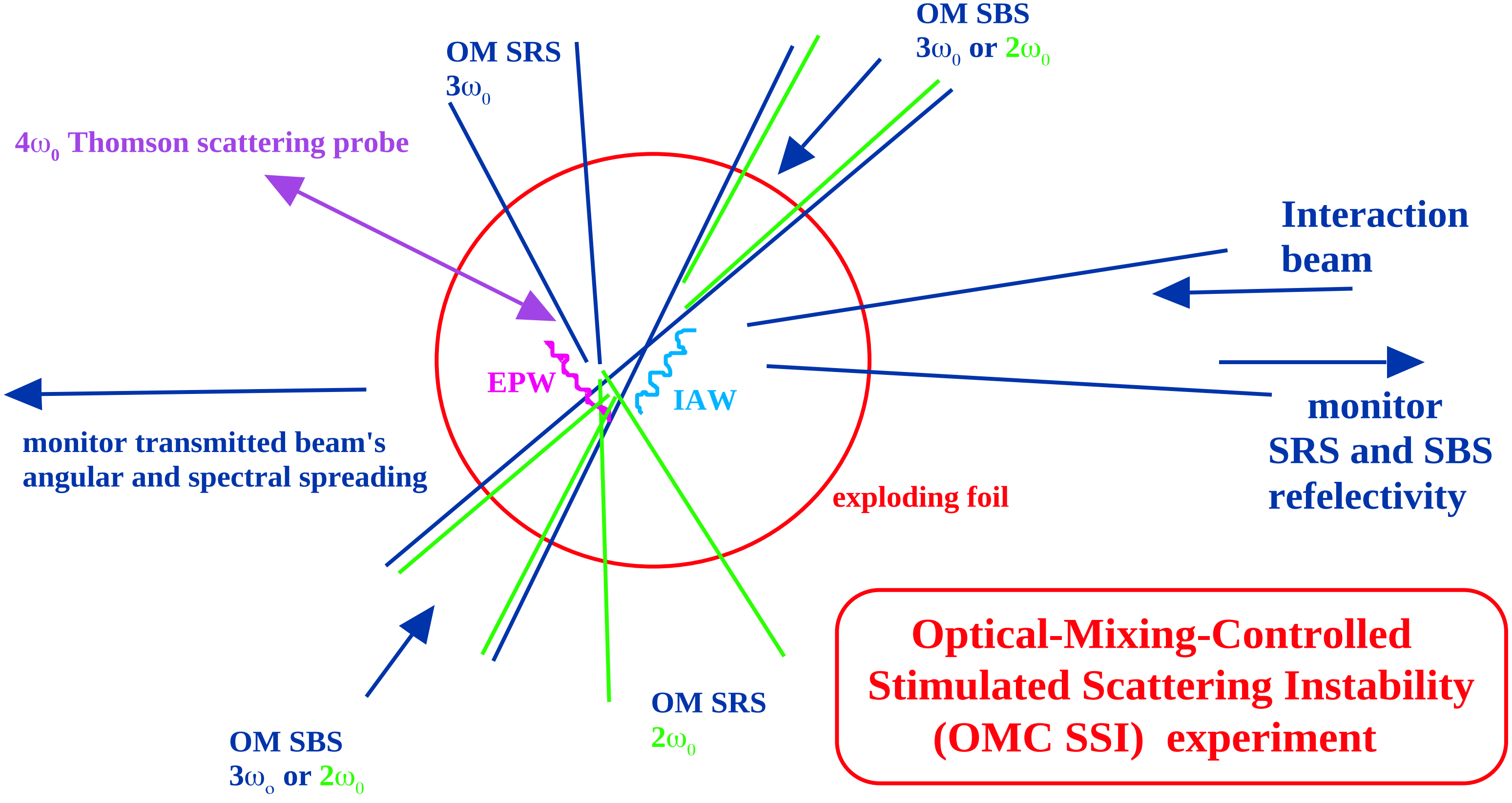
Controlled levels of interaction between waves and instabilities.



**Optical-Mixing-Controlled Stimulated Scattering Instability (OMC SSI) experiment**

# The Configuration of our Omega Blue-Green OMC SSI Experiment

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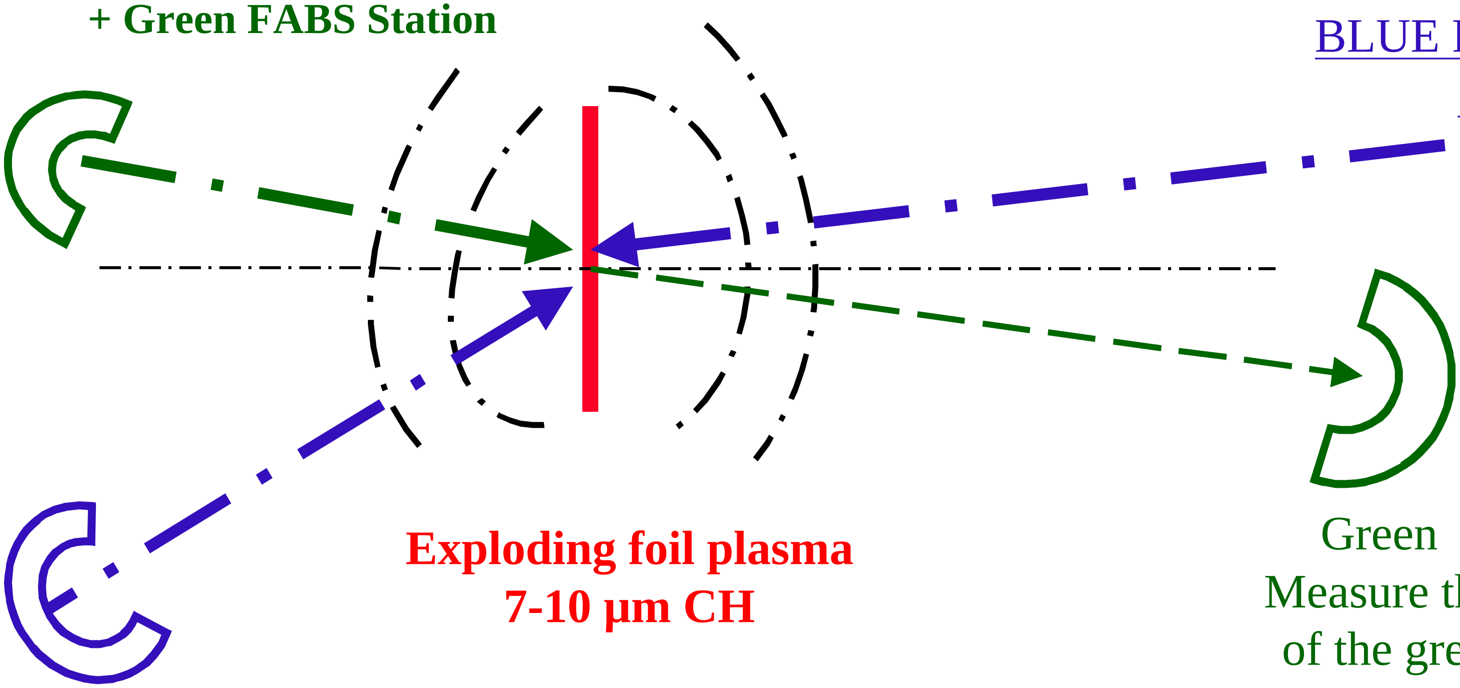


**GREEN PROBE BEAM**
**(BL25) @ P 9**
**+ Green FABS Station**

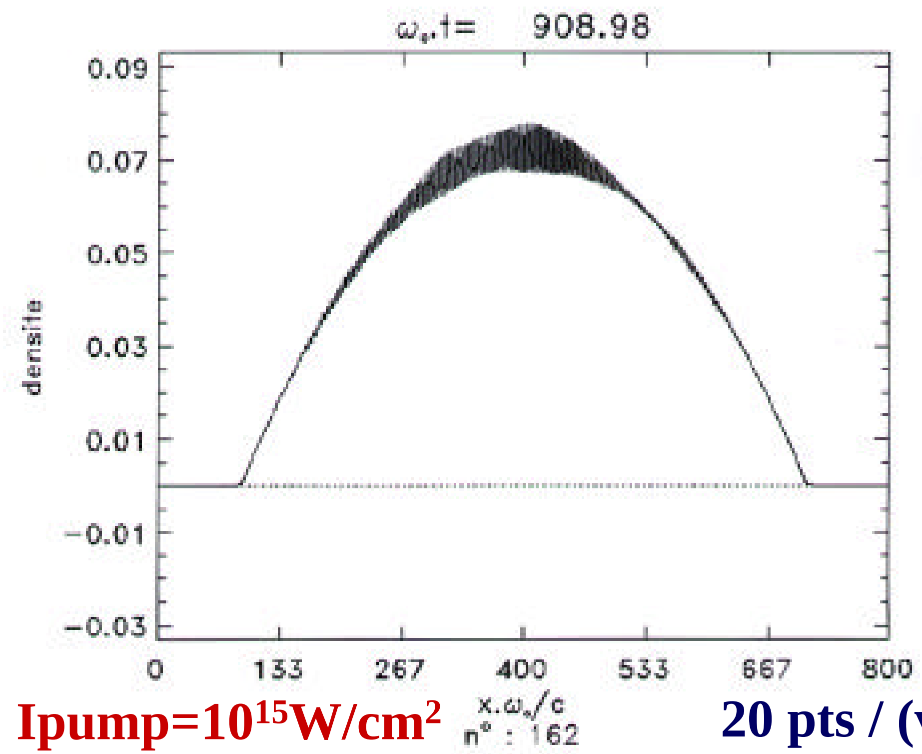
BLUE PUMP BEAM
BL 55

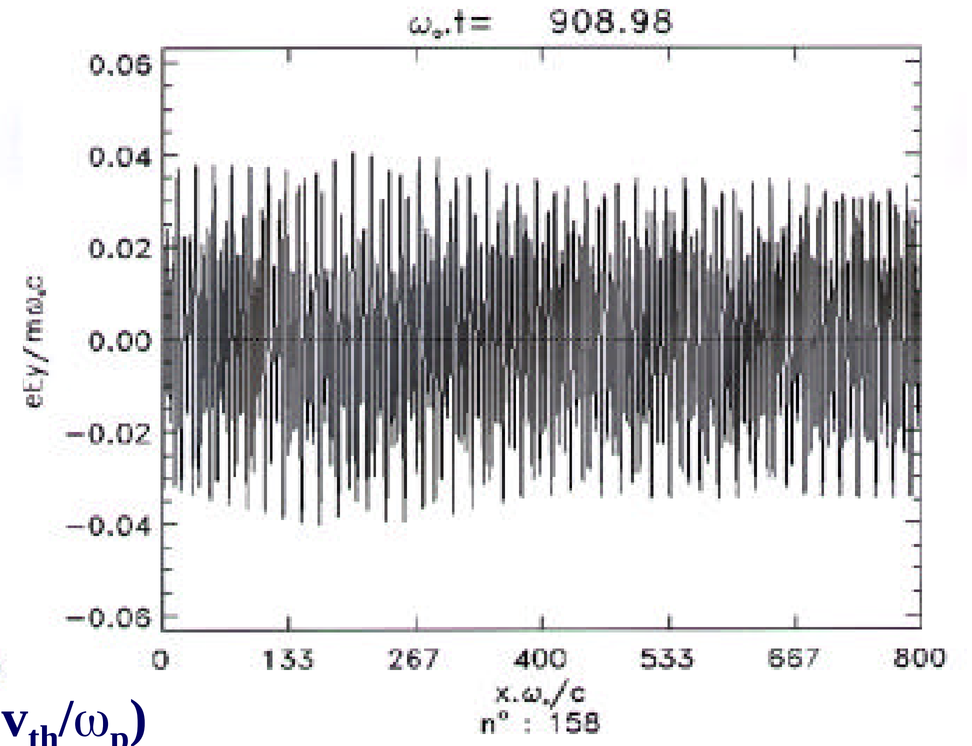
**Exploding foil plasma**
**7-10 μm CH**

Green TBD station
Measure the transmission
of the green probe beam

**BLUE SRS GENERATING BEAM**
**BL12**
**+ Blue FABS station**

# Vlasov-Maxwell Simulations of Optical Mixing Generated EPWs (Nancy Collaboration) Blue-Green





**Ipump=$10^{15}$W/cm$^2$**
**$I_{probe}/I_{pump}$ = 0.5**
**$n/n_c$=0.072**
**$T_{e,keV}$ = 3.0**

**20 pts / $(v_{th}/\omega_p)$**
**$N_X$ points = 4096**
**$N_V$ points = 256**
**Rise time = 100 $\omega_p^{-1}$**

**0.15 μs/grid point on a single processor**

# OMC SSI Using IAWs: Experimental Configuration on Omega

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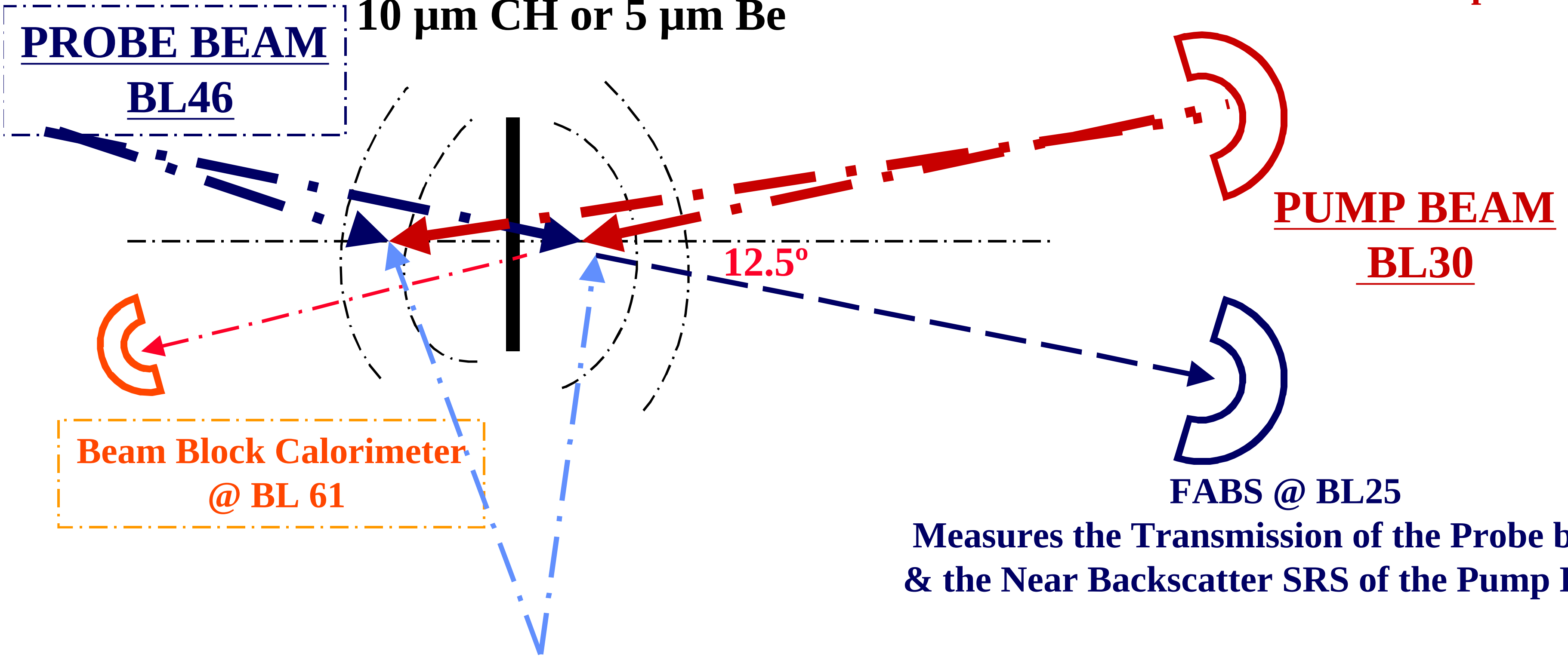

**Exploding foil plasma**
**10 µm CH or 5 µm Be**

**FABS @ BL30**
**Measures SRBS and SBBS of the Pump Beam**

**PROBE BEAM**
**BL46**

**PUMP BEAM**
**BL30**

12.5°

**Beam Block Calorimeter**
**@ BL 61**

**FABS @ BL25**
**Measures the Transmission of the Probe beam**
**& the Near Backscatter SRS of the Pump Beam**

**Point the probe +/-500µm from target center along the target normal**
**Point the pump +/-500µm from the taret center along target normal**

# What Are Our Goals with OMC SSI Omega Exp’ts?

- By optically mixing a pump and probe beam, we generate large amplitude IAWs at or near the Mach -1 surface of an exploding foil target (on the pump side of the density peak).
- We measure how this reduces the SRS and SBS backscattering levels of the pump when the probe/pump energy ratio is high enough. See when effect starts and when it saturates per SRS wavelength or plasma density window near the sonic point.
- We hunt for laser beam localization or crossing volume localization effects by varying the pump focal position.

# 2D Lasnex Simulations Suggest the Following Hydrodynamic Conditions for 10µm CH Foil Plasmas

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$\omega_{pe}^2 = \frac{4\pi n_e e^2}{m_e}$ $\frac{e^2}{\hbar c} = \frac{1}{137}$

**(1) Sn006 DPP on 500 J 1ns pump, no probe.**

**2ns of SG3 DPP heaters 3kJ per ns (3 beams/ ns/ side).**

**Interaction beam starts at 1.5 ns**

**(2) Sn006 DPP on 500 J 1ns pump, sn006 DPP on 1ns probe.**

**2ns of SG3 DPP heaters 3kJ per ns (3 beams/ ns/ side).**

**Interaction beams start at 1.5 ns**

**Inferred (best fit) density profile has the shape:**

$$n = n_{\text{peak}} \exp\left[-\left(z/L_\alpha\right)^\alpha\right]$$

(1)

35%

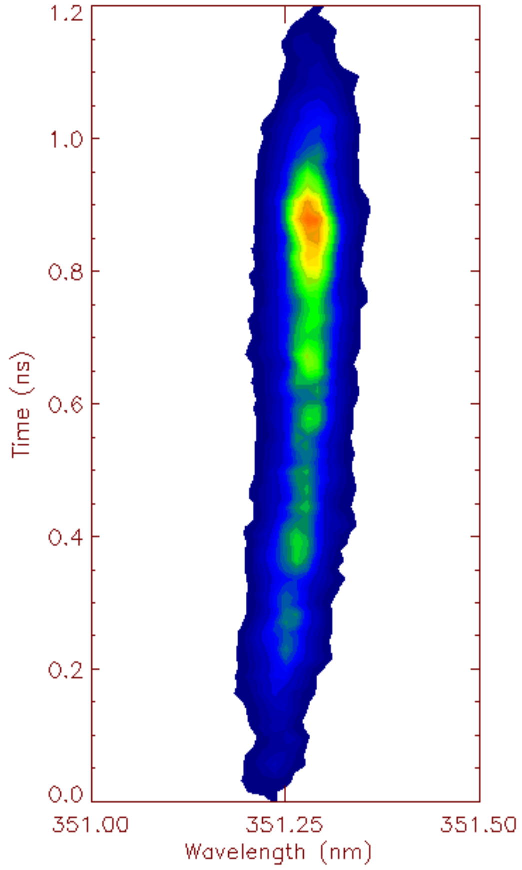
| time | n(peak)/nc | alpha | L_alpha microns | L_n microns | L_v microns | n(M=-1)/nc | Te keV peak | Te keV (M=-1) | Ti keV peak | A (M=-1) |
|---|---|---|---|---|---|---|---|---|---|---|
| t=1.5 ns | 0.132 | 1.55 | 675 | 657 | 320 | 0.096 | 2.02 | 1.9 | 1.02 | 0.5 |
| t=2.0 ns | 0.085 | 1.5 | 867 | 811 | 440 | 0.059 | 2.08 | 2 | 0.97 | 0.23 |
| t=2.5 ns | 0.063 | 1.55 | 954 | 930 | 450 | 0.046 | 1.35 | 1.3 | 0.95 | 0.25 |

| time | n(peak)/nc | alpha | L_alpha microns | L_n microns | L_v microns | n(M=-1)/nc | Te keV peak | Te keV (M=-1) | Ti keV peak | A (M=-1) |
|---|---|---|---|---|---|---|---|---|---|---|
| t=1.5 ns | 0.146 | 1.55 | 667 | 636 | 343 | 0.102 | 2.07 | 1.92 | 1.03 | 0.55 |
| t=2.0 ns | 0.100 | 1.55 | 770 | 677 | 418 | 0.068 | 2.15 | 2.01 | 1.04 | 0.3 |
| t=2.5 ns | 0.065 | 1.6 | 1049 | 1061 | 431 | 0.051 | 1.53 | 1.47 | 0.95 | 0.27 |

(2)

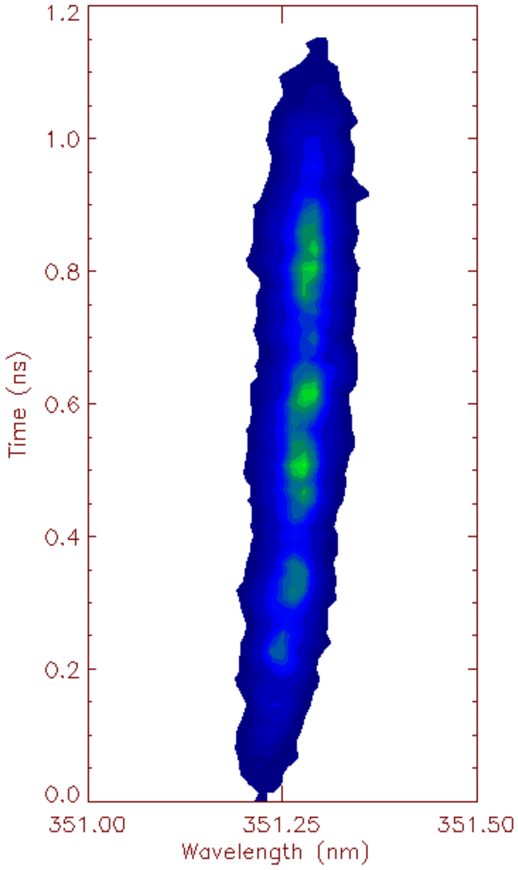
42%

# Transmission Spectra of the Probe When $I_{probe}/I_{pump}$ =1/2, Show Energy Transfer Especially at Late Time

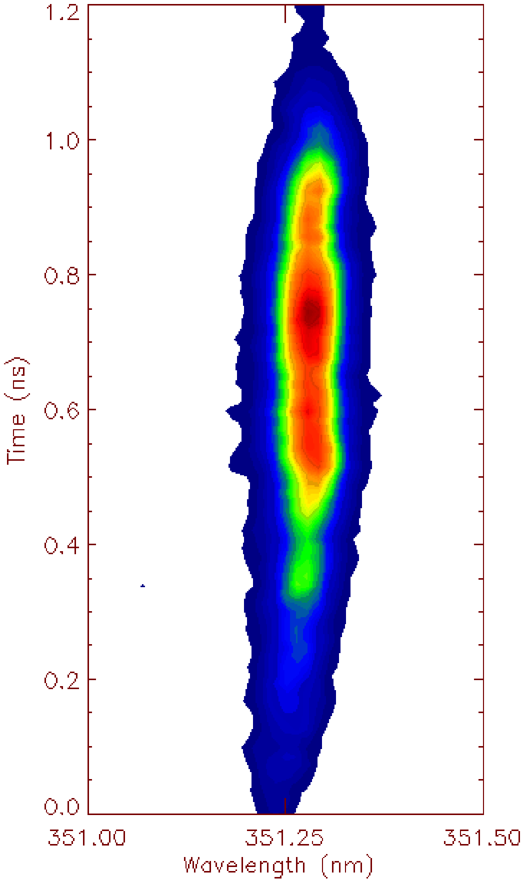


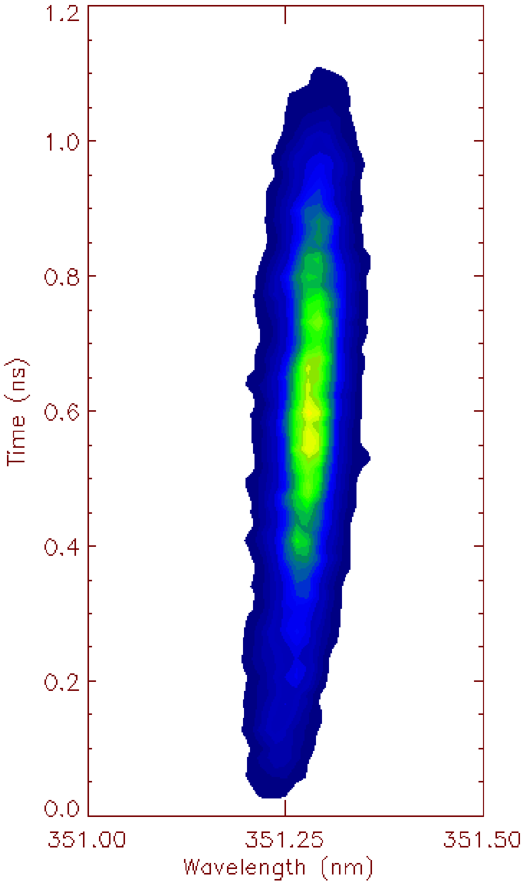
Mach -1

Mach +1



# Energy transfer Is Present Throughout Laser Pulse at $I_{probe}/I_{pump}$ =1/15 ie in the Small Signal Gain Regime





# Probe Transmission Characteristics: Demonstration of IAW Generation

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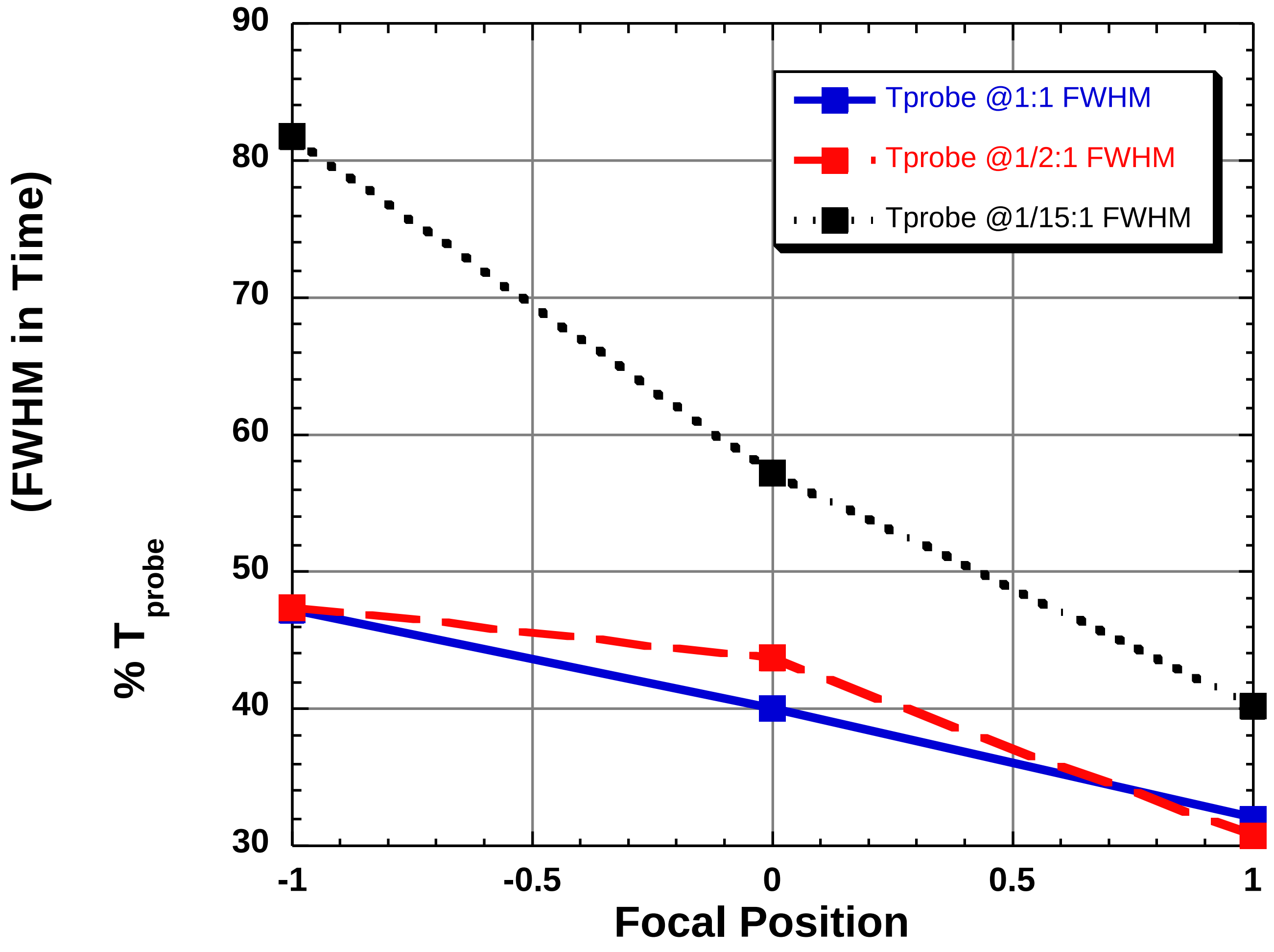
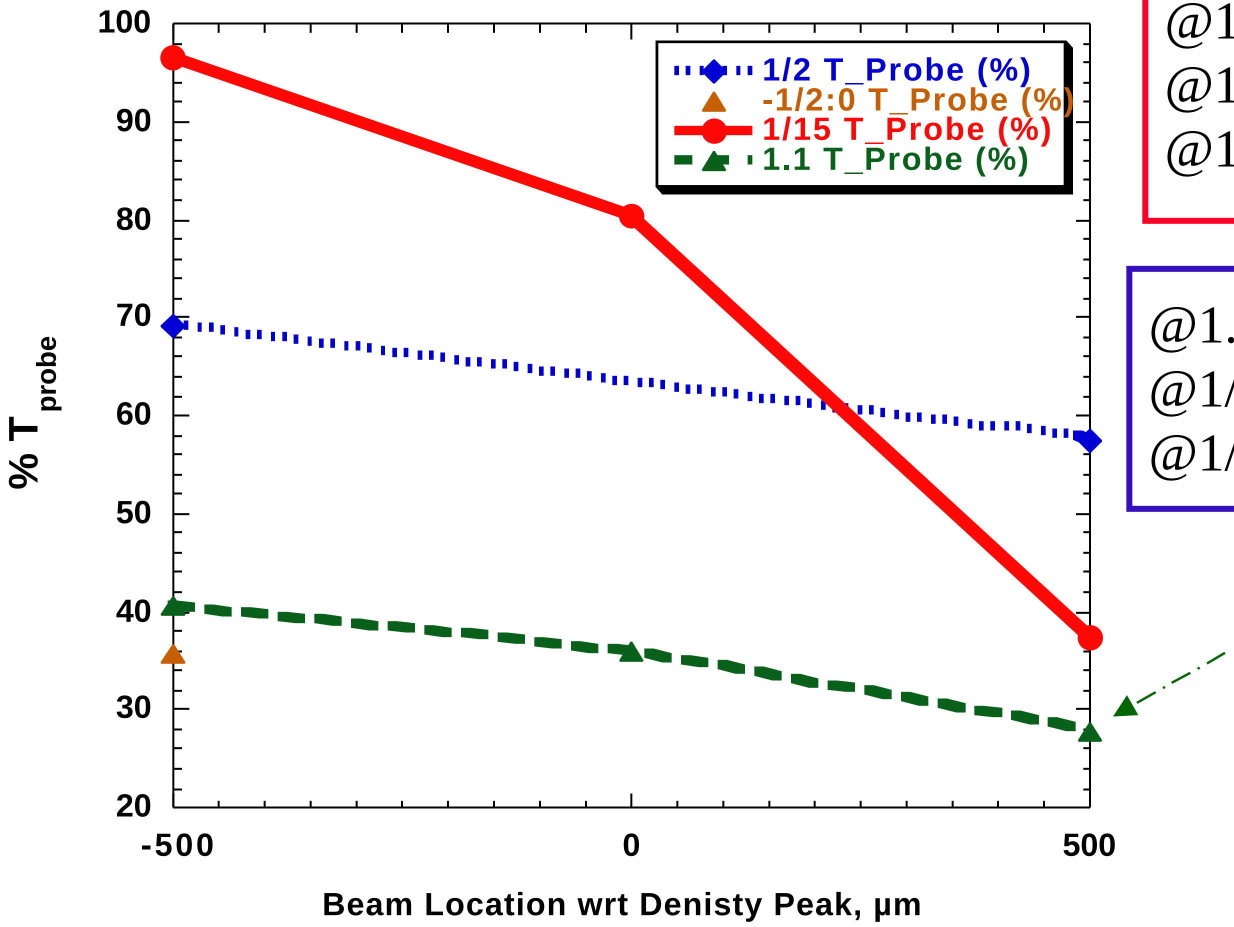


# Transmitted Beam Story Involves Euler’s number?



@1.1:1 $T_{Probe}|^- / T_{Probe}|^+ = 1.44$
@1/2:1 $T_{Probe}|^- / T_{Probe}|^+ = 1.21$
@1/15:1 $T_{Probe}|^- / T_{Probe}|^+ = 2.6$

@1.1:1 $T_{Probe}|^- / T_{pump\ off}|^+ = 1.13$
@1/2:1 $T_{Probe}|^- / T_{pump\ off}|^+ = 1.92$
@1/15:1 $T_{Probe}|^- / T_{pump\ off}|^+ = 2.67$

**Note that @1.1:1 the transmission of the probe is LESS at +500 µm than in the Pump off Case. This is because the Pump is now taking energy away from the Probe via Optical Mixing as their roles have reversed!**

# First Observation of Greater than 100% Crossed Beam Energy Transfer (Be Plasmas)

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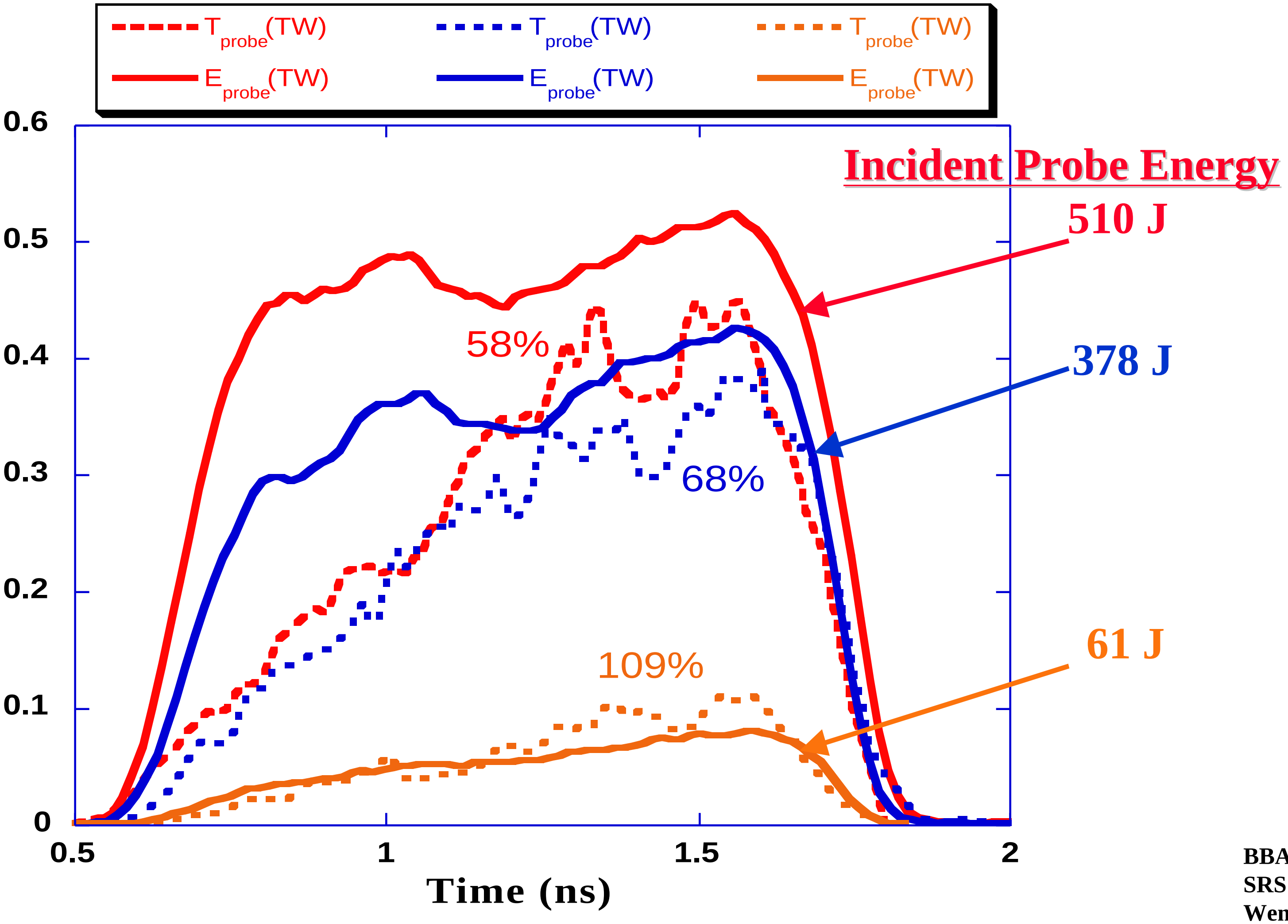

BBA OMC SSI
SRS / SBS Saturation
Wente 4-5-02

# Demonstration of SRS Suppression in the Appropriate Wavelength/density Window Dictated by the Localized IAW at the Mach -1 Surface

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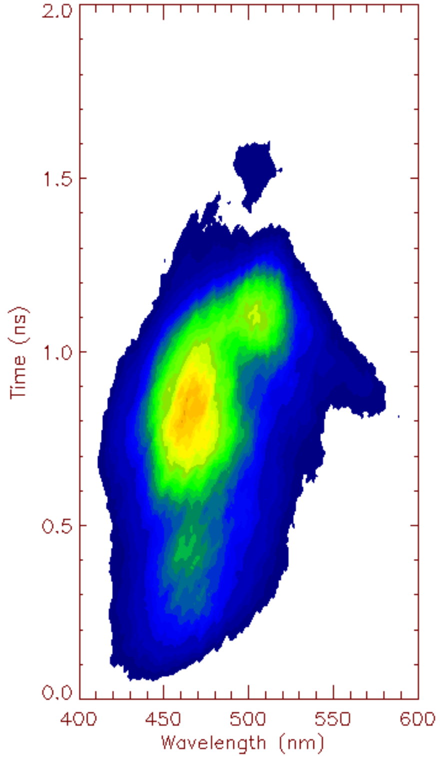
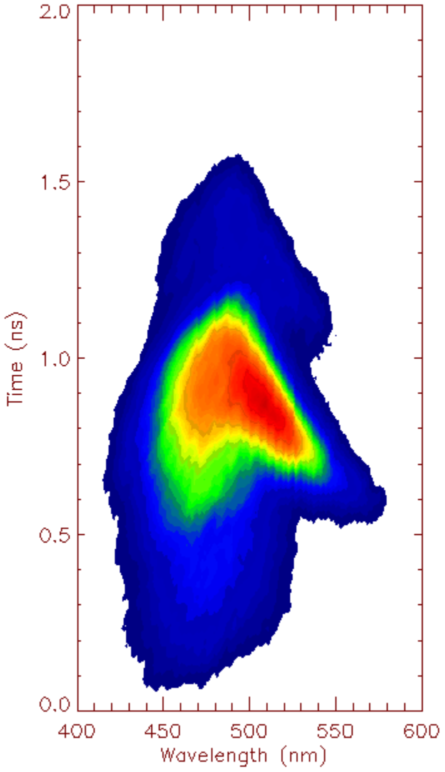
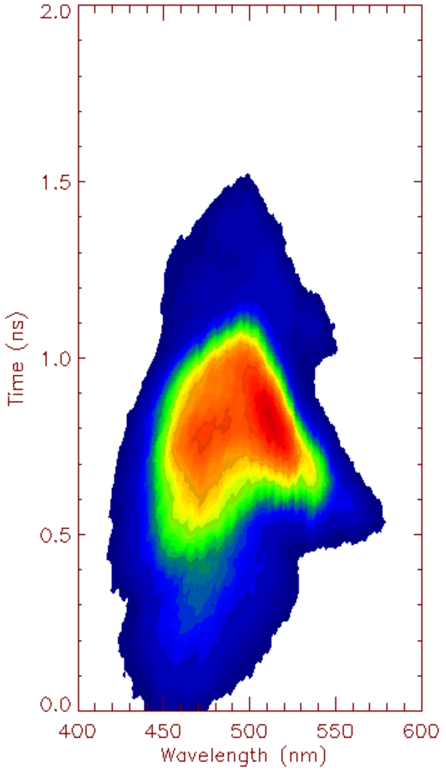
**19944 Focus = - 500µm**
**$E_{probe}/E_{pump}$= 511/511**



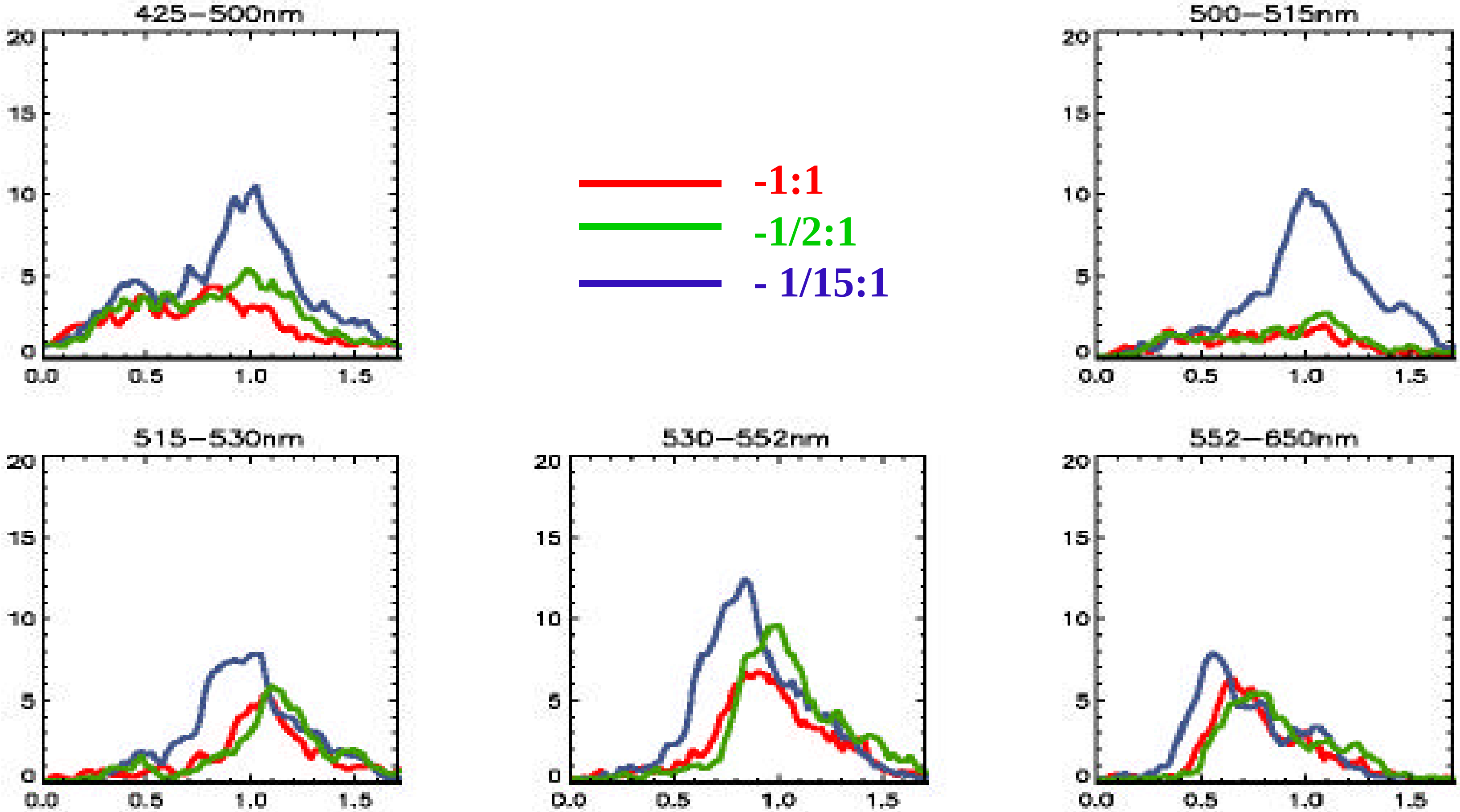
**19945 Focus = + 500µm**
**$E_{probe}/E_{pump}$= 508/508**



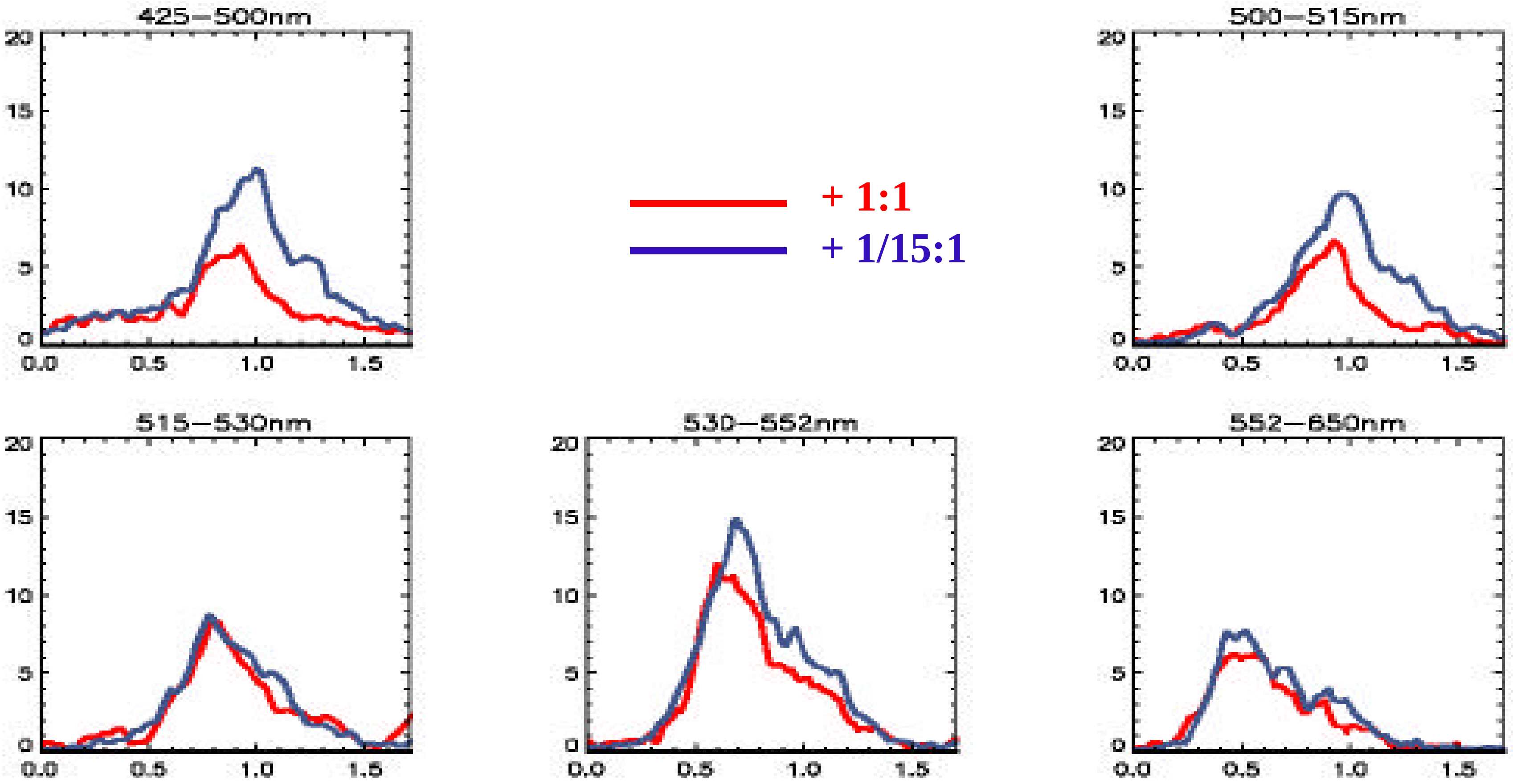
**Shot# 19946 Focus = + 500µm**
**$E_{probe}/E_{pump}$= 56/509**



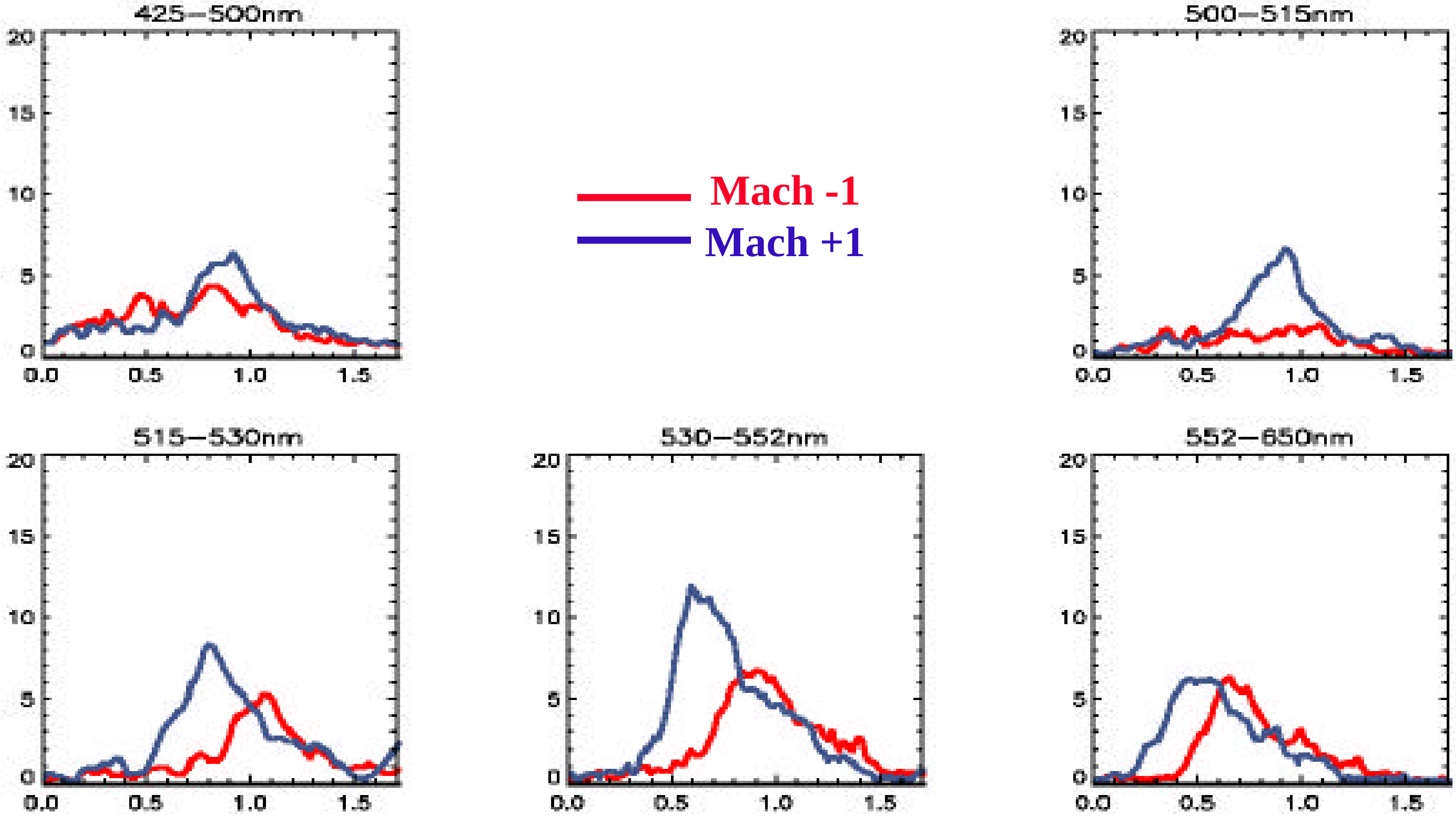
# Comparison of SRS Power (GW) vs Time (ns) in 5 Wavelength Partitions at Mach -1



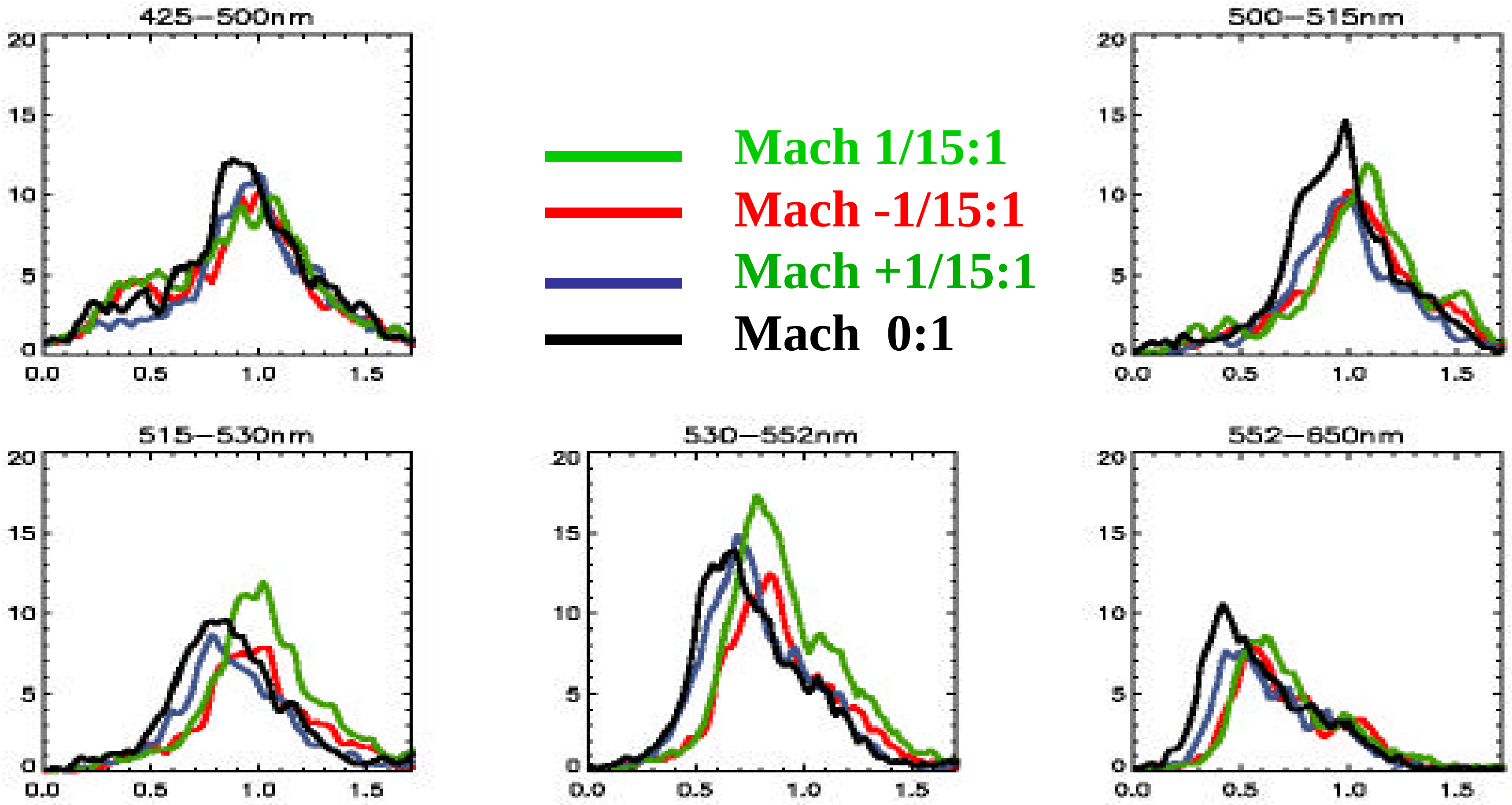
# Comparison of SRS Power (GW) vs Time (ns) in 5 Wavelength Partitions at Mach +1



# Comparison of SRS Power vs Time
# Mach +1 vs Mach -1 at 1:1



# Reassuringly, Very Little Difference Exists When Probe Intensity is Too Low (1/15:1) to Generate Larger Amplitude IAWs



# Reduction in SRBS is 4.8x in 500-515 nm Window when Large IAW Is Present

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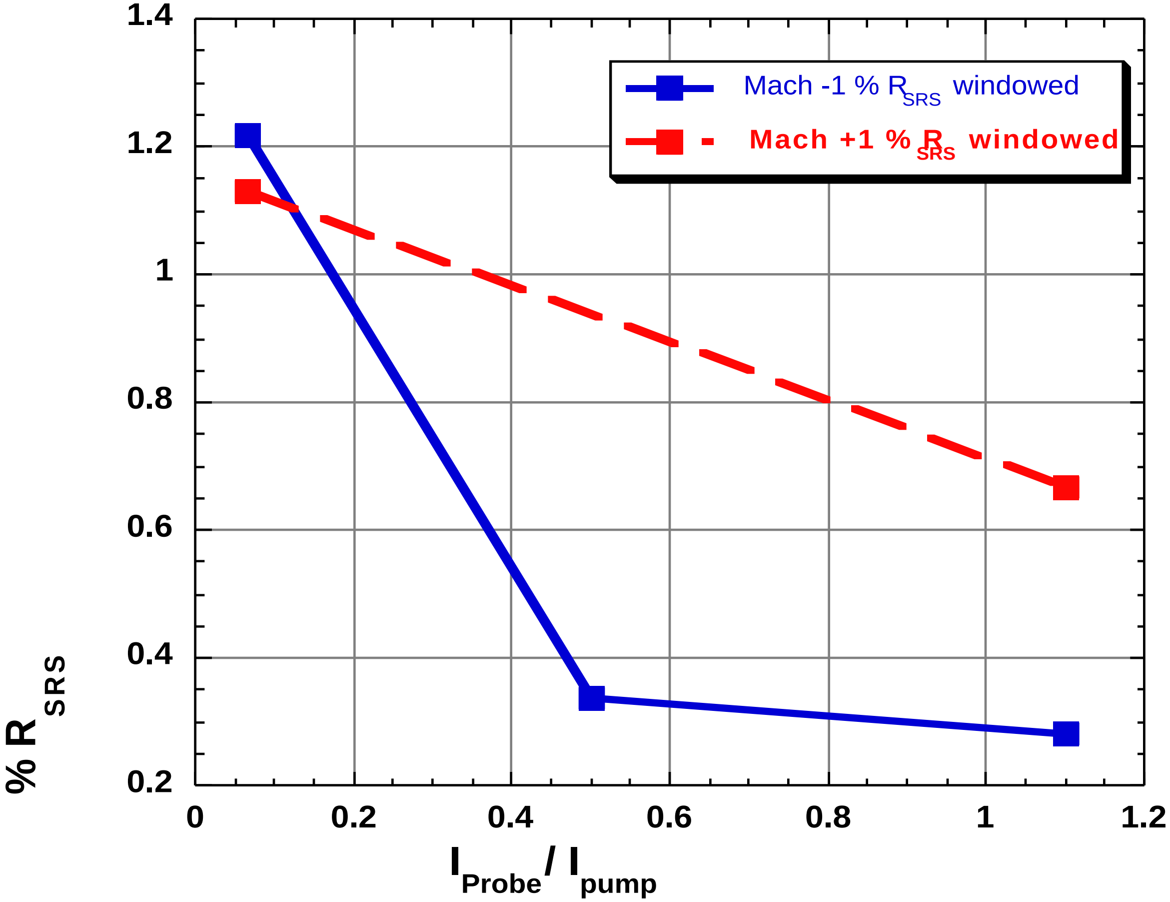
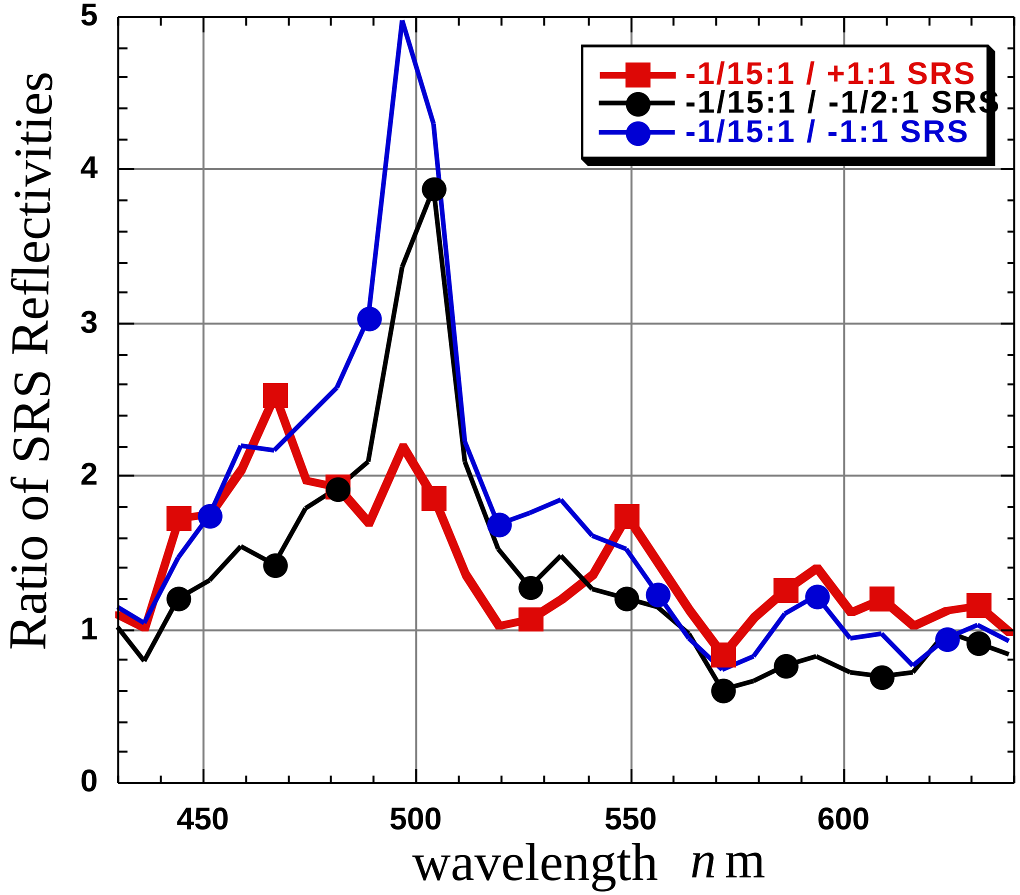


**Interval in time where SRS at 1/15:1 looks different than SRS at 1:1 or 1/2:1 defines the time window used in this figure.**

# Wavelength or Density Selectivity of SRS Suppression Is Due to Large Amplitude IAW Presence at Mach -1


Reduction of SRS is strongly peaked
in the 490-515 nm wavelength Range

Interval in time where SRS at 1/15:1 looks different than SRS at 1:1 or 1/2:1 defines the time window used in this figure.

Interval in space where SRS at 1/15:1 looks different than SRS at 1:1 or 1/2:1 corresponds to the wavelength range 490-515 nm.

This in turn corresponds to (assuming $T_e = 2$ keV) the density range

$$0.04 < n_e / n_c < 0.052$$

While 2D Hydro Simulations indicate

$$0.046 < n(M= -1) / n_c < 0.09$$

# SRBS Reduction as a Function of Probe Energy Is Stronger in the Weak IAW Damping Limit

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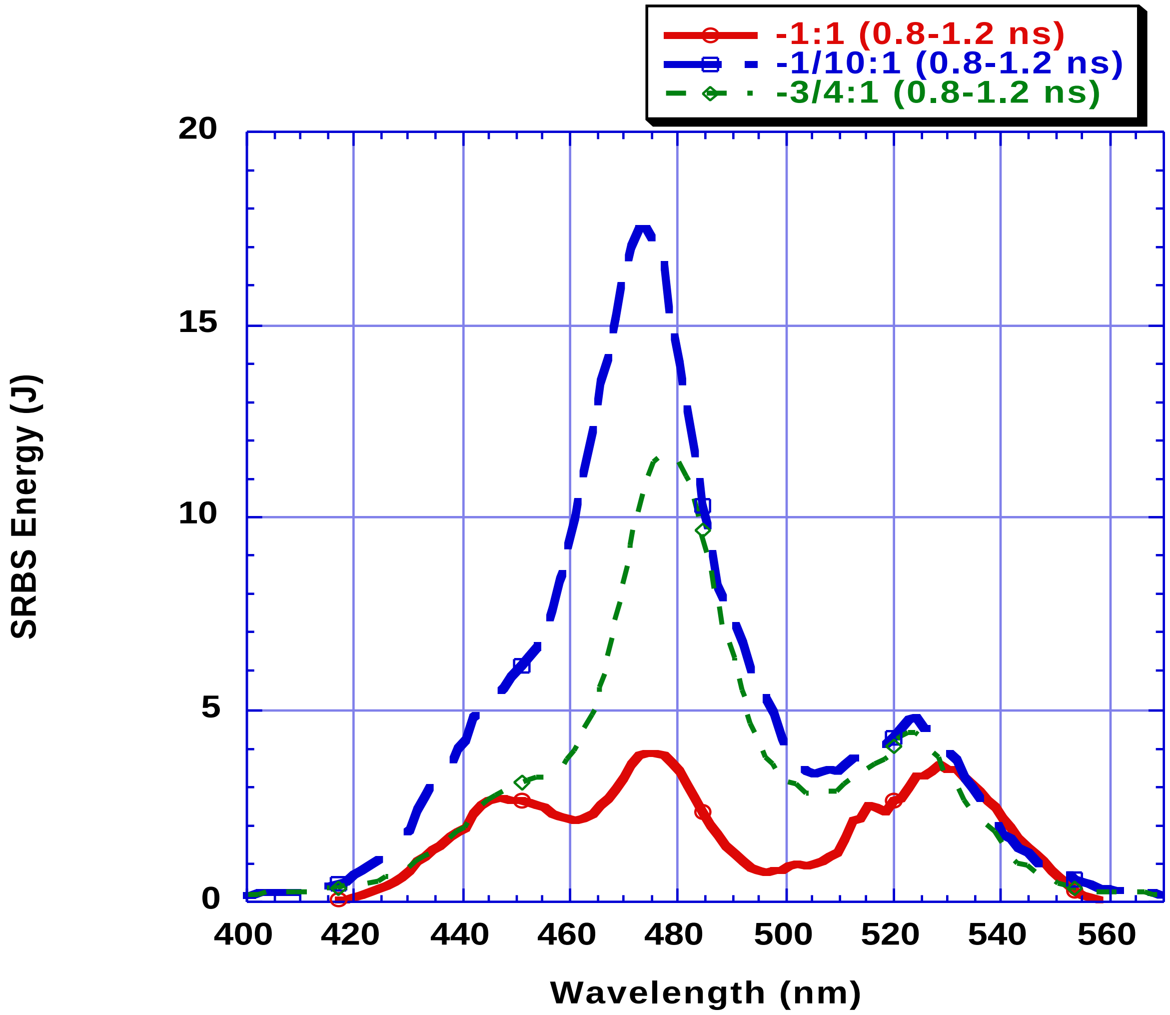

**SRBS Suppression factors**
**x 7-8 in Be plasmas**
**as opposed to x 4-5 in CH**

**Overall SRS levels**
**are between 4 and 8%**

# Conclusions

- We have demonstrated a strong suppression (x 5) in SRS backscattering reflectivity (normally of order 7%) in the presence of large amplitude ion acoustic waves in the strong IAW damping limit (10 µm CH) and (x7) in the strong IAW damping limit (5 µm Be).
- We have demonstrated that the wavelength range of SRS suppression overlaps strongly with the Mach -1 region of the plasma where a resonant IAW was driven by comparing to LASNEX predictions of hydro evolution.
- We have demonstrated that this should not be due to the seeding of LDI IAWs suppressing SRS, for even at 1/15:1 the seed source available for LDI would have been many orders of magnitude higher than thermal noise, yet +/-/0 focusing had no effect at 1/15:1 and all were like 0:1. Focusing changes only made a difference at higher energy ratios.
- We have seen > 100% transmission in the weak probe limit in Be targets making the energy transfer argument quite certain.

# Optical Diagnostics Used

- FABS stations deployed on BL 25 and BL30.
- Deploy Raman and Brillouin (3 $\omega_0$) channels on both.
- Streaked spectra and calorimetry data
  (time and wavelength averaged) on both SRS and SBS channels.
- Beam block calorimeter deployed on BL61
  which is opposite BL30, which is our pump beam.
- This adds up to measuring: i) the Transmission of the Probe (BL 46)
  [streaked spectroscopy and calorimetry of BOTH SRS and SBS channels]
  at the FABS station on BL25,
  ii) the reflectivity of the pump (BL30)
  [streaked spectroscopy and calorimetry of BOTH SRS and SBS channels]
  at the FABS station on BL 30 and
  iii) the transmission of the pump (BL30)
  [just calorimetry of the SBS channel] at BL61.
- P510 data on all shots from BL46 and BL 30.