White Paper for Frontiers of Plasma Science Workshop

Interactions of plasmas and waves on:

"Progress in development plasma ultraintense laser (PUL) as compact SRBS powerful amplifier & compressor"

Szymon Suckewer, Princeton University

1.Recent presentation by Nat Fisch on "Toward Improving Efficiency of Large Diameter Fsec SRBS Amplifier in Plasma" (Potential Applications for Tabletop X-Ray Lasers in "Water Window") at SSAP Symposium 2015, NNSA, Santa Fe, March 11-12/2015

- Past very exciting SRBS results, in particular 2- passes amplification and compression in plasma
- Quite recent 2D simulations to lead to optimal experimental conditions
- Important experimental result: Creation Very Good Plasma Channel after more than 2 years very intensive works

2. Good initial results with large diameters of pumping seed laser beams in large diameter plasma channel for powerful SRBS laser with intensities of 10^{20} W/cm^2 and higher is expected in not far future

3. Potential application to X-Ray Laser in "Water Window" at 3.4nm, 4nm and at 1nm and shorter wavelength using very compact PUL.
   - Recent XRL result with indication of high gain at 4nm in He-like CV ions in fast recombination scheme
   - Projection (illustration) for compact recombination XRL pumped by

SSAP Symposium 2015, NNSA, Santa Fe, March 11-12/2015

Toward Improving Efficiency of Large Diameter Fsec SRBS Amplifier in Plasma

Potential Applications for Tabletop X-Ray Lasers in "Water Window"

PI: Szymon Suckewer (Presented by Nat Fisch); Princeton University

⇒SRBS Amplification and Compression for Fsec Laser

- Laser Pumping and Seeding in Small Plasma Diameter
- Two-Passes SRBS

⇒Improving Efficiency in Larger SRBS Amplifier

- New Plasma Conditions (~8x larger diameter)
- New Laser Pumping(> 16 X higher pump energy)
- Importance of Channeling
- Toward Higher Efficiency

➔Why to Pump Recombination XRL with SRBS Fsec Laser

Motivation for Developing Ultraintense SRBS Laser

◆ X-Ray Lasers : • With pumping intensities ~ 10^{19} W/cm^2 lasing at 3.4nm in CVI ions for transitions into ground states can be generated.

- Lasing without inversion (LWI) in XUV/XR: possibility to have additional lasing at 4.0nm in He-like ions (theory by M.Scully and his group)
- With >10^{21} W/cm^2 lasing at wavelengths < 1nm would be possible for transitions into ground states of mid-Z ions
- Fsec XRL at very high intensities : HHG with XR : possibility to generate hard X-rays
- From HHs in X-ray region possibility to obtain strong **X-ray Asec pulses**

◆ Fast ignition : • Scheme for inertial fusion with sub-nsec pulses to ignite a compressed capsule [Y.Ping, R.Kirkwood et al, *Phys. Plasmas* **16** (2009)];

• Concept by T.Tajima and G.Mourou (*Phys. Rev. Special Topics*, **5** (2002) of using ~ 10 fs pulses with intensities of I ~ 10^{25} W/cm^2;

• Support for Tajima-Morou concept by V.Malkin and N.Fisch, *Phys.Plasmas*, **12** (2005)

Acknowledgements

Earlier SRBS Expts
Y.Ping – PhD Thesis 2002
W.Cheng – PhD Thesis 2007
J.Ren - Ph.D

Recent SRBS Expts
A.Morozov - Ph.D
S.Li - PhD Thesis 2013
D.Turnbull- PhD Thesis 2013
Y.Luo – Post Doc 2014

X-Ray Laser Develop.
A,Morozov – PhD
Y.Luo – PhD (Thesis 2013)
Y.Avitzour-PhD(Thesis 06)

SRBS Theory (Re Earlier Expts)
N. Fisch V., Malkin, G.Shvets - Princeton
J.Wurtele - UC Berkeley

SRBS Modeling (Re Earlier Expts)
Ryan Lindberg - UC Berkeley

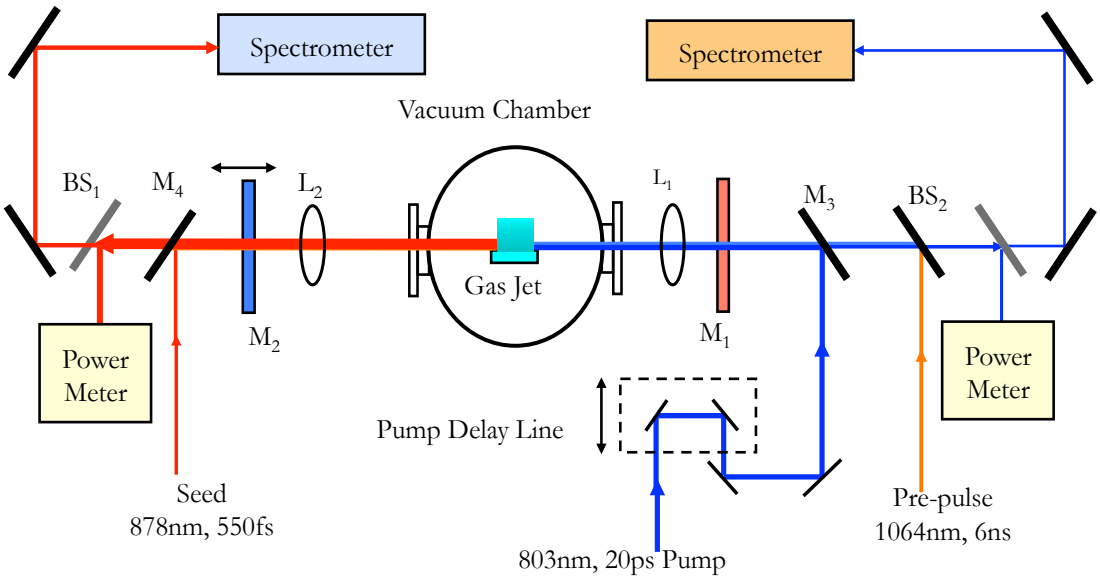
Recent SRBS Modeling
P.Sprangle- Prof (U.Md; NRL)
D.Gordon - PhD (NRL)
L.Johnson – Grad Student
J.Ren - PhD (LANL)

Theory: Q.Cohrence in "WW"
M.Scully – Prof (PU,TAMU)
A.Svidzinsky – PhD (TAMU)

Support : $ NSF, NNSA/DOE $

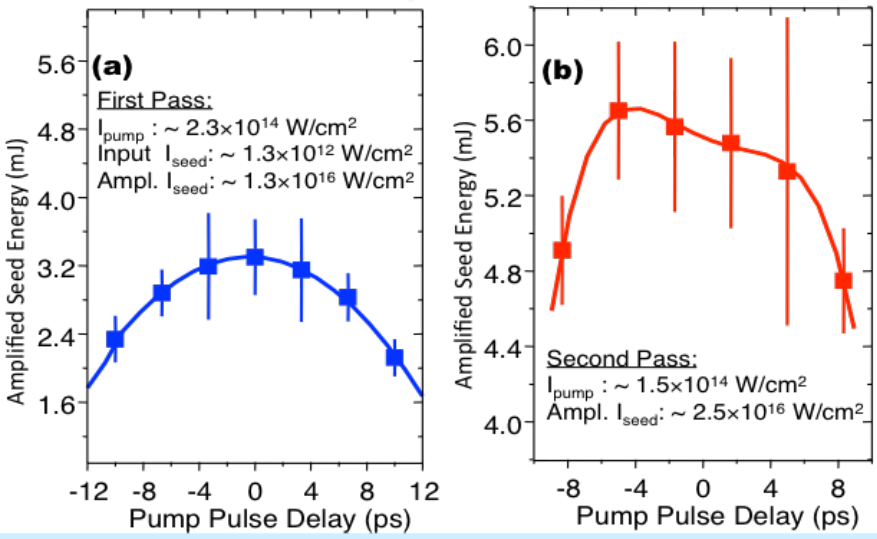
Double Pass Experiment in Small Diameter Plasma Channel

Very important first demonstration



Dichroic mirror M_1 has high reflectivity at 878nm, and high transmission at 803nm and 1064nm. And dichroic mirror M_2 has high reflectivity at 803nm, and high transmission at 878nm and 1064nm. The temporal alignment between pump and seed for 1st pass was adjusted by the Pump Delay Line, and for 2nd pass was adjusted by the horizontal position of M_2 (50μm diameter 2mm plasma channel)

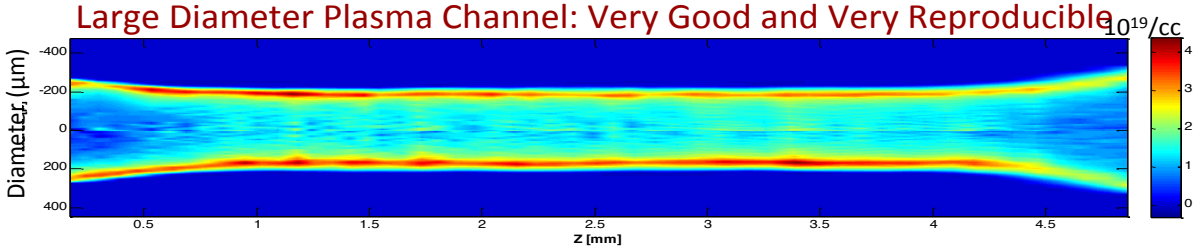
Double Pass Experiment : Results



*(a) For **1st pass:** Input pump energy **~ 87mJ** and **input seed energy ~16uJ***
*(b) For **2nd pass:** Pump energy **~56mJ** and **input seed energy ~3.3mJ***
***(c) For 2 passes**: average efficiency (not corrected): **6.4%**; After correction for pump-seed interaction length :**η~12%** , near axis: **η~17%** (S.Li- PhD Thesis 2013)*

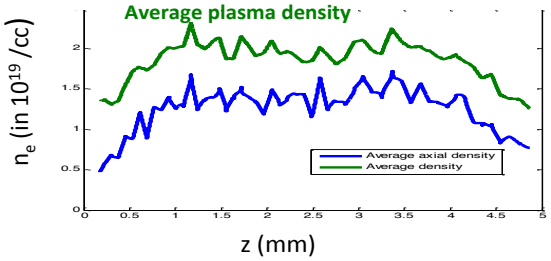
New SRBS Setup to Reach Intensity ~10^{20} W/cm²

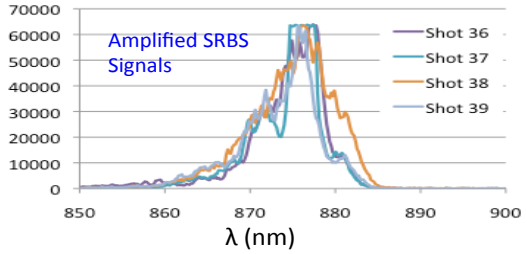
Large Diameter Plasma Channel: Very Good and Very Reproducible



2D Plasma Density Map from Abel Inverted Original Interferogram

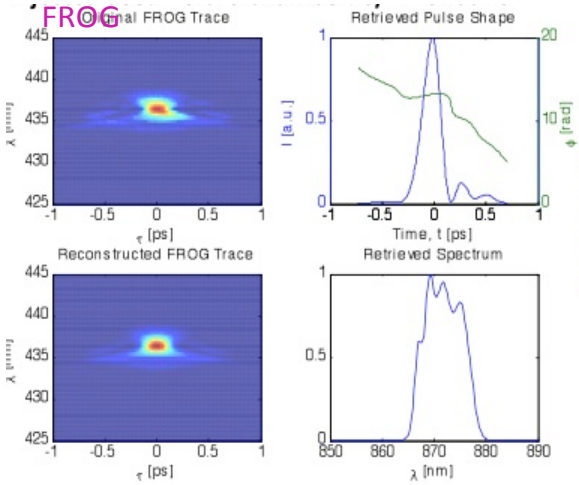
Data

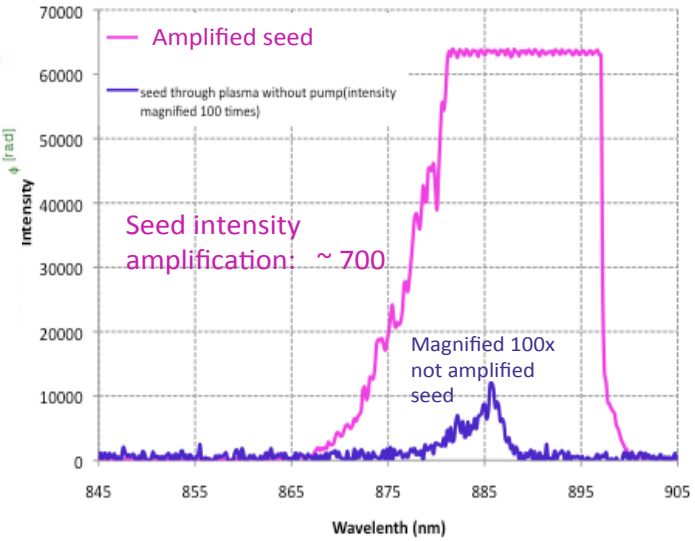




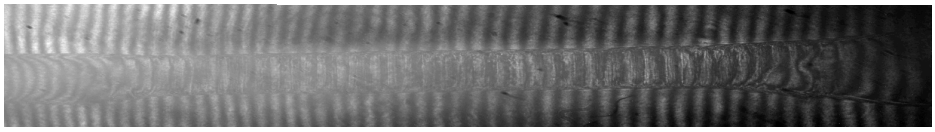
SRBS Amplifications and Spectra: Large Diameter Channels

Pulse duration from single shot FROG





Pump: 210mJ,
Seed input: 75μJ
Axicon : 20ns delay
<η>~15%



Concept of Table Top Recombination X-Ray Laser Pumped by Ultrahigh Intensity SRBS Fsec Laser