Conf-950476--1

LA-UR- 95-1333

*Title:* SDOSS: A SPATIALLY DISCRIMINATING, OPTICAL STREAKED SPECTROGRAPH

*Author(s):* J. A. Cobble
S. C. Evans
J. C. Fernandez
J. A. Oertel
R. G. Watt
B. H. Wilde

*Submitted to:* 12th International Conference on Laser Interaction and Related Plasma Phenomena
Osaka, Japan
April 24-28, 1995



**Los Alamos**
NATIONAL LABORATORY

# SDOSS: a Spatially Discriminating, Optical Streaked Spectrograph*

J. Cobble, S. Evans, J. Fernández,
J. Oertel, R. Watt, B. Wilde

*Los Alamos National Laboratory, Los Alamos, NM 87545*

SDOSS is employed to study broadband laser scattering encompassing SBS, SRS, and the 3/2-ω signature of two plasmon decay for ns-scale laser-plasma experiments with 351- or 527-nm drive. It uses a Cassegrain telescope to image scattered light from a laser plasma onto a field stop. The telescope magnification and the stop aperture provide spatial discrimination of target plane scatter. A UV lens relays the image to a 0.25-m spectrograph which is lens coupled to a streak camera with an S-1 photocathode. The streak output is imaged onto a CCD camera. In its 512x480 pixel array, the CCD covers a spectral range from 200 to 800 nm with 4-nm resolution and can be adjusted to look from 350 to 1060 nm. The sweep speed is variable with full window values of 30, 12, 6 ns, and faster. An optical fiducial provides a spectral and temporal marker.

On the Livermore Nova laser, SDOSS has been used to determine spatial density in gas-filled hohlraums from SRS signals. At Trident in Los Alamos, it has been employed for similar measurements with long scale length plasmas in SBS and SRS seeding experiments. It has proven to be a versatile tool for studying the physics of laser-generated plasmas.

Optical spectroscopy of scattered laser light from inertial confinement fusion (ICF) targets is important to verify the economy of laser coupling to the target and to diagnose the target performance. The former helps quantify laser energy converted to plasma waves, which can scatter laser light from the target and can generate hot electrons that might preheat the fusion capsule. The latter determines the plasma conditions in the target thus providing the opportunity to improve target design and behavior. An example of an optical diagnostic is the subject of this paper: SDOSS, a spatially discriminating optical streaked spectrograph, which obtains time dependent scattered laser spectra from discrete regions of the target

The major novelty of SDOSS (1) is perhaps its spatial discrimination, which derives from a Cassegrain telescope imaging target light onto an intermediate focal plane. A field stop is located in this plane where an aperture limits the light which passes on to a collection lens for injecting scattered light into the spectrograph. The magnification of the Cassegrain and the aperture diameter determine the spatial resolution. At present, transverse resolution is 200 μm.

---

* This work supported by the US DOE.

The output signal from the spectrograph is lens coupled to a streak camera and subsequently lens coupled again into a CCD camera for storage by a computer. The resulting data are images of the time-versus-wavelength streak for light coming from the selected portion of the target. Figure 1 illustrates the optics of SDOSS, all of which are compatible with ultraviolet (UV) light. The streak photocathode is a

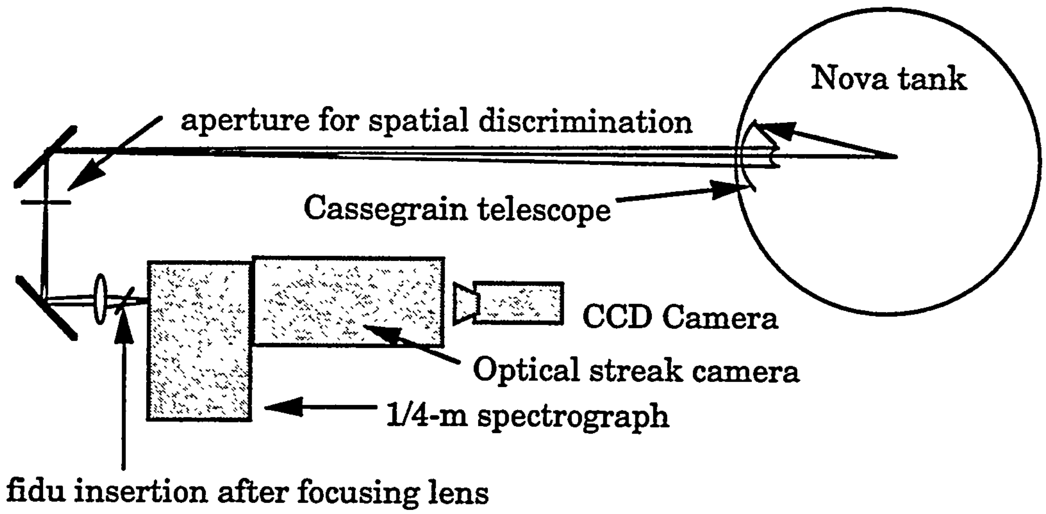


FIGURE 1. Line drawing of SDOSS on the NOVA laser chamber

UV-extended S-1 (2), which gives it sensitivity from 200 to greater than 1000 nm. The 0.25-m spectrograph and the CCD pixel size combine to give a system spectral resolution of 4.5 nm. With a 6-ns window on the streak, the temporal resolution is about 100 ps.

Another novel feature of the system is the broad spectral coverage. With 351-nm laser drive, data extending from 200 to over 700 nm are recorded. This allows simultaneous recording of three primary parametric instabilities (3): stimulated Brillouin scattering (SBS) at near 351 nm, stimulated Raman scattering (SRS) between 351 and 702 nm, and two plasmon decay (TPD) with its signature near 234 nm. SDOSS has been run in this mode at NOVA (4). On the Trident laser, which operates at 527 nm, a simple grating rotation in the spectrograph permits wavelength coverage from 400 to 1100 nm. At Trident (5), the Cassegrain telescope was not available, and glass lenses were used to focus the scattered light. Therefore, the two-plasmon signal at 351 nm was not accessible in this case.

SDOSS has been employed on two laser facilities: NOVA and Trident. It has demonstrated its capability for resolving plasma parameters and has helped in the understanding of target issues (6 and 7).

The NOVA experiments have probed gas-filled hohlraums (8). Nine of the ten NOVA beams are used to heat the hohlraum as shown in Fig. 2. After ~400 ps, a 1-ns probe beam of intensity $6 \times 10^{14}$ W/cm$^2$ is turned on. In the figure the SDOSS window sees the overlap of the probe with a single heater beam at a distance of 840 µm from the hohlraum axis. On other targets, the window has been moved left or right to observe probe sidescatter at different distances from the axis. The sidescatter angle is 104°.

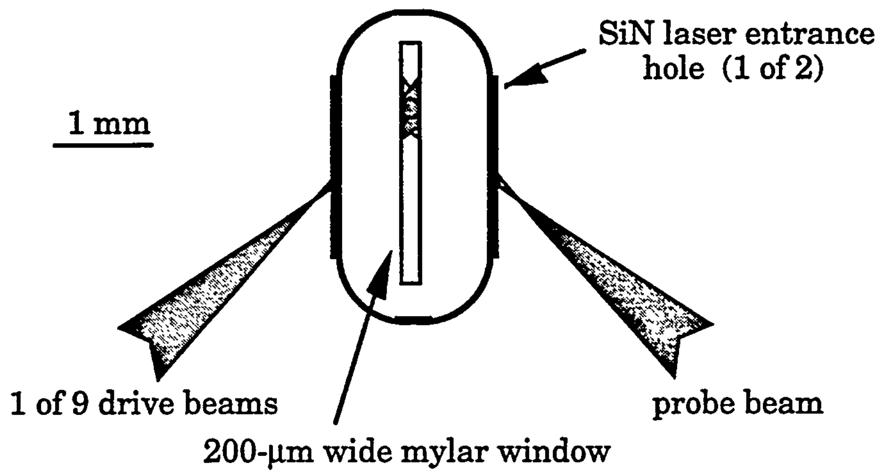


FIGURE 2. Side view of a gas-filled NOVA hohlraum from SDOSS -- The circle shows the 200-μm SDOSS field of view. Five beams enter the target on each end.

The nominal gas fill is one atmosphere of neopentane. This gas, when photoionized by the laser and by x rays, corresponds to a plasma density of 12% of the critical density ($\pi mc^2/e^2\lambda^2$) for the 351-nm drive. However, shocks in the plasma are launched when the laser entrance windows and the interior gold wall are illuminated. These cause a variation in plasma density within the hohlraum. In order to estimate the density, we examine the SRS spectrum. SRS arises when the incident laser light pumps an electron plasma wave and is shifted to longer wavelengths. The spectrum tells from what density the scattered light comes, and since SDOSS has spatial resolution corresponding to the line of sight through the probe beam, we have a point measurement of density in this case at 840±100 μm.

A sample scattered spectrum from a CCD image is shown in Fig. 3. This is raw data with no correction for photocathode sensitivity or spectrometer calibration. The wavelength scale is calibrated with a Hg lamp, which shows that the dispersion is linear. The spectrum is filtered with two high reflectivity rejection filters: one which reduces the 351-nm light by approximately 100 times and another which does the same at 527 nm. (The latter is necessary for when NOVA operates with green drive.)

Signals from three parametric instabilities are indicated by the spectrum. The strongest when corrected for sensitivities is the 351-nm SBS. Next is the TPD signal at 234 nm. This is a surprise since TPD originates at quarter critical density and is strong evidence of a factor of two enhancement of the plasma density somewhere within the small volume of the hohlraum from which light is scattered. The third instabilities is SRS with a spectrum extending from 460 to 700 nm. The gap in the spectrum from 500 to 550 nm is due to the green rejection filter. (In spite of this filter, stray specular reflection of unconverted, unfocused green light can be seen in the streak. This has been eliminated in other data with shine shields to prevent laser light from striking the outside of the target. Then, the green filter can be removed to look at SRS in this spectral region.) Finally, the 700-nm feature is believed to be SRS at near quarter critical. While possibly some of the signal is due to second order SBS, the shape of the profile is different, and the relative intensity

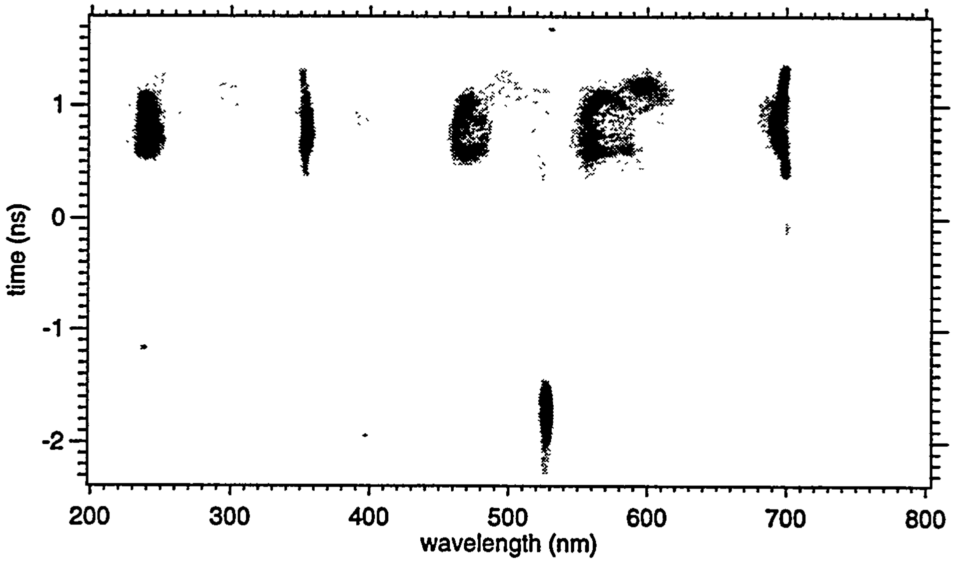


FIGURE 3. Seen through a diagnostic slot at the intersection of two beams inside the hohlraum, simultaneous spectra of SBS, SRS, and TPD are observed by SDOSS.

of first and second order Hg I 365 in the calibration denies the likelihood that this is second order 351. The breadth of the SRS therefore suggests scattering from many densities within the scattering volume and presents a picture of the complicated dynamics in the interior of these hohlraum targets.

The utility of SDOSS is also shown by backscatter experiments on Trident. In this case, resolution is dictated by the laser spot size of 125 μm rather than by a field stop aperture. The scattering angle as shown in Fig. 4 is 180° along the probe beam and the wavelength 527 nm. The laser irradiance is about $1 \times 10^{15}$ W/cm$^2$.

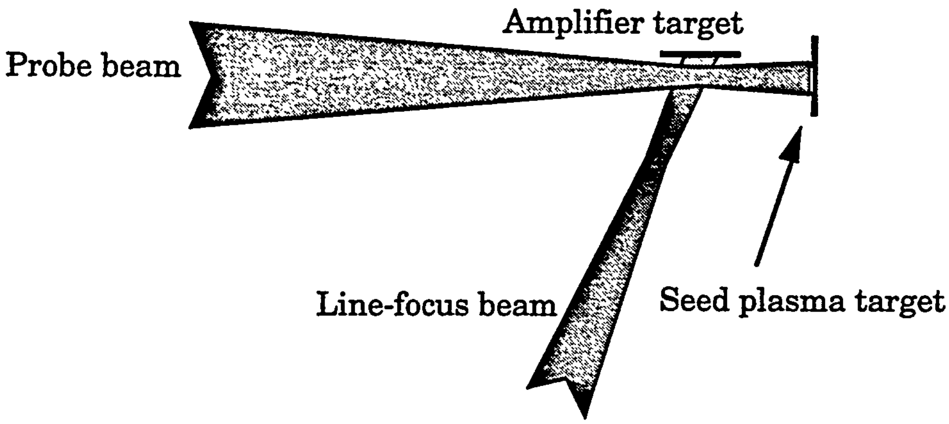


FIGURE 4. SDOSS looks at 180° backscatter of the probe beam on this complex Trident target.

SDOSS was used to characterize two parts of the target for an instability seeding experiment (6). The seed part of the target was a CH-coated Au disk on which the probe beam was normally incident. The second part of the target, more than a hydrodynamic expansion distance away, was a CH foil illuminated by the line focus of a second laser beam. The probe beam passed within 200 μm of the surface of this foil and tangent to it. With the CH foil alone, SDOSS verified the existence of a 5%-critical plasma within the probed plasma volume. Figure 5 below shows the SDOSS data for the seed plasma only. In time, the wavelength of peak

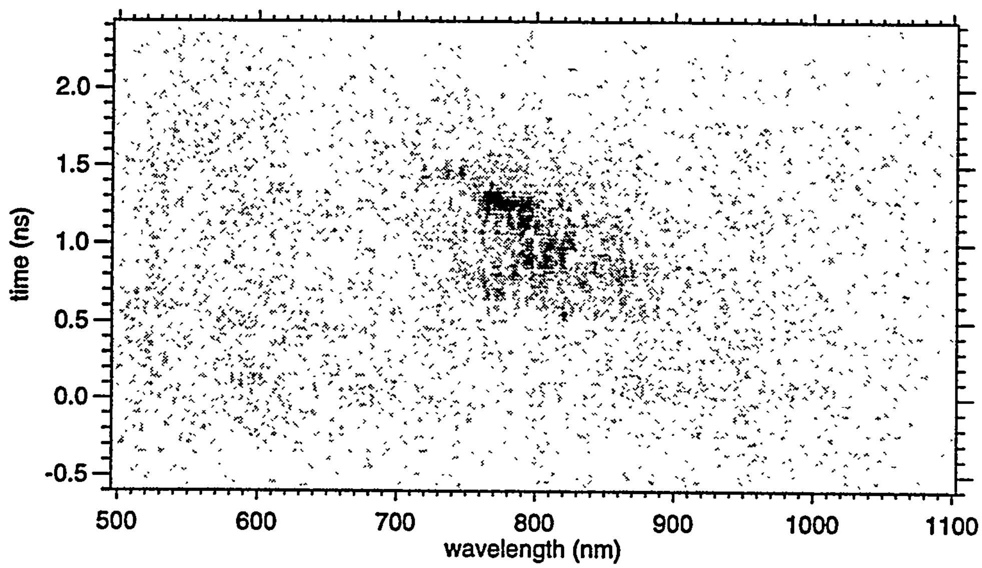


FIGURE 5. The electron density of peak SRS gain is seen to fall off with time for a Au disk target. The 527-nm SBS is attenuated by a high reflectivity green rejection filter.

SRS falls off from 825 to 740 nm. This corresponds to the expansion of the plasma and shows that the density at which SRS gain is highest is blowing down as the plasma expands. In 1 ns, this density drops from about 12% to 7% critical.

These measurements were vital to proper control of this experiment. In both the NOVA and Trident, SDOSS is demonstrated to be a versatile diagnostic for recording optical spectra and understanding the plasma physics of complex experiments.

# REFERENCES


1. Cobble, J. A., Fernández, J. C., Wilde, B. H., Evans, S., Jimerson, J., Oertel, J., Montgomery, D. S., Gomez, C. C., "Simultaneous temporal, spectral, and spatial resolution of laser scatter from parametric plasma instabilities", submitted to *Rev. Sci. Instru.*, Jan., 1995.

2. Turner, E. B. ,"Optical and Ultraviolet Techniques", Huddlestone, R. H., Leonard, S. L., eds., *Plasma Diagnostic Techniques,* New York: Academic Press, 1965, ch. 7, p. 351.

3. Kruer, W. L., The Physics of Laser Plasma Interactions, Redwood City, CA: Wesley Publishing Co., 1988, chs. 6-8, pp. 57-94.

4. Hunt, J. T., Speck, D. R., *Optical Engineering* 28, 461 (1989).

5. Moncur, N. K., Johnson, R. P., Watt, R. G., Gibson, R. B., "TRIDENT: a versatile high-power Nd:glass laser facility for ICF experiments", accepted for publication in *Appl. Optics,* 1995.

6. Fernández, J. C., Cobble, J. A., Gobby, P. L., Lindman, E. L., Montgomery, D. A., Rose, H. A., Wilde, B. H., Wilke, M. A., "Brillouin backscatter and seeding mechanisms in NOVA hohlraums", paper TuP-5, this conference.

7. Wilde, B. H., Fernández, J. C., Hsing, W. W., Cobble, J. A., Delamater, N. D., Failor, B. H., Hockaday, R. G., "The design and characterization of toroidal-shaped NOVA hohlraums that simulate Nat. ignition facility plasma conditions for plasma instability experiments", paper TuP-4, this conference.

8. Fernández, J. C., Cobble, J. A., Failor, B. H., Hsing, W. W., Rose, H. A., Wilde, B. H., Bradley, K. S., Gobby, P., Kornblum, H., Montgomery, D. A., "Dependence of stimulated Brillouin scattering on laser intensity, laser f number and ion species in hohlraum plasmas", submitted to *Phys. Rev. Lett.,* Jan., 1995.