Greatly enhanced acoustic noise and the onset of stimulated Brillouin scattering*

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Experiments using near-infrared to ultraviolet lasers offer the potential to study the acoustic noise in plasmas. As the onset of stimulated Brillouin scattering (SBS) has come to be closely examined, the evidence indicates that the acoustic noise may often or always be far above thermal levels. Evidence regarding the noise is reported here, from two recent experiments which confirmed the theoretically anticipated onset behavior for SBS. In one case, the noise appears to be greatly enhanced above thermal levels. In the other case, the data place an upper limit on the noise level. There is physical grounds to believe that enhanced acoustic noise may be ubiquitous in plasmas, even in the absence of plasma instabilities which drive turbulence. © *1997 American Institute of Physics.* [S1070-664X(97)96005-5]

I. INTRODUCTION

It is one of the simplest properties of a plasma that the action of the plasma pressure, opposing modulations of the ion density, establishes low-frequency oscillations of the plasma having $\omega = c_s k$, where c_s is the sound speed in the plasma and ω and k are the frequency and wave number of the wave, respectively. In unmagnetized plasma, the acoustic dispersion relation describes the behavior of the fluctuating ion oscillations throughout the phase space of low-frequency waves, for $k\lambda_D < 1$, where λ_D is the Debye shielding length in the plasma.[1] We are concerned here with the acoustic waves in laser-produced plasmas. These waves have some ambient noise level and may be driven to large amplitude *via* stimulated Brillouin scattering or other nonlinear mechanisms.

Not much has been known regarding the noise level of acoustic waves. The level of thermal fluctuations is well established (see, for example, Ref. 2), but it has been unclear what level of noise might actually be present in plasmas that are not strongly unstable. In typical laboratory plasmas whose density is within a few orders of magnitude of 10^{10} cm^{-3}, the noise fluctuations are too weak to measure. (The acoustic turbulence can be seen when it is driven by some unstable mechanism such as a beam plasma instability.) Even in plasmas irradiated by CO$_2$ lasers, at densities up to 10^{19} cm^{-3}, measurements of the acoustic noise would be extraordinarily difficult; such measurements have not been reported. In denser plasmas, however, it becomes feasible to use lasers to measure the properties of the noise, averaged over a scattering volume of many λ_D^3.

Though feasible, such studies have not been undertaken on any of the many lasers worldwide which might have done so, as the various research programs are more-often concerned with the saturated amplitude of phenomena that are thought to impact one or another application, such as laser fusion[3] or x-ray lasers.[4] In spite of this lack of attention, there are good reasons to study the acoustic noise level in this environment where it is feasible. The obvious motivation is that the acoustic noise provides the starting point for any subsequent driven process involving acoustic waves, but there are others. Our conclusions regarding the noise in laser plasmas may extend to all plasmas. In addition, any waves present in the plasma impact all the others through mode coupling. This can, in principle, alter the threshold, growth rates, and saturation dynamics of any instability.[5] Further, we offer the hypothesis that the acoustic noise may play a role in the global hydrodynamics of the plasma. There are some well-documented discrepancies in the calculation of plasma hydrodynamic behavior using fluid codes.[6–9] It is fundamentally not clear where the laser energy went in these cases. It may have gone into acoustic modes.

Because light scattering is the most feasible way to detect the acoustic noise, and because such scattering evolves into stimulated Brillouin scattering (SBS) as the intensity of the light source is increased, it is appropriate to review the studies of SBS before discussing measurements related to acoustic noise. We undertake this next. After that, we review prior evidence regarding acoustic noise and introduce new evidence from two recent experiments which also studied the onset of SBS. We then discuss these observations and conclude.

II. STUDIES OF STIMULATED BRILLOUIN SCATTERING

One might hope to have obtained evidence regarding acoustic noise levels from past studies of stimulated Brillouin scattering, which grows from acoustic noise. However, despite the existence of more than 60 papers reporting ex-

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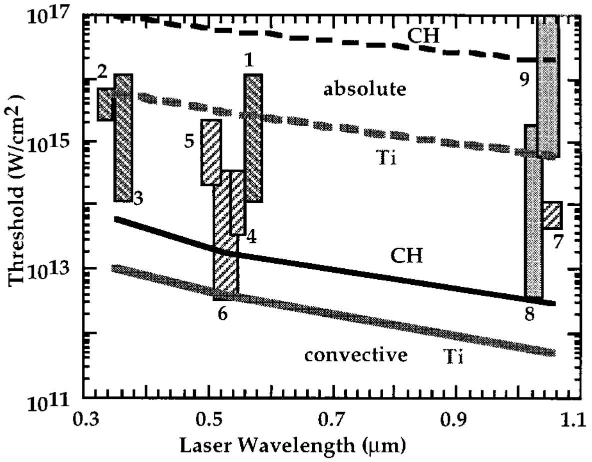

FIG. 1. The intensity required to exceed the damping threshold for convective or absolute stimulated Brillouin scattering depends upon laser wavelength as shown, for Ti and CH plasmas. The assumed parameters for CH are density $n=0.1n_c$ (n_c is the critical density), electron temperature $T_e=1$ keV, ion temperature $T_i=T_e/3$, for which $\Gamma_s=0.14c_sk$. The parameters for Ti are $n=0.05n_c$, $T_e=3$ keV, $T_i=T_e/2$, for which $\Gamma_s\sim 0.01c_sk$. The experiments shown include typical ''laser fusion'' scaling experiments (1. Drake,[46] 1989; 2. Powers,[47] 1995; 3. Fernandez,[29] 1996, onset experiments 4. Bradley,[35,37] 1993/95; 5. Watt,[28] 1996; 6. Drake,[30] 1996; 7. Tikhonchuk,[27] 1996, and short pulse experiments 8. Baldis,[31] 1993; 9. Baton,[34] 1994).

perimental studies of ''SBS'' from laser-irradiated plasmas dating back more than 20 years, no data showing growth from noise were published prior to 1993. There have been many high-quality studies of the nonlinear saturation of SBS in preformed plasmas of well below critical density, irradiated by CO$_2$ lasers of ~ 10 μm wavelength. See for example Refs. 10–18. One of these[10] reported evidence of the convective finite-length threshold and two others[15,19] discussed the implications of data at high reflectivity for damping thresholds and for growth from noise. In experiments using ''short-wavelength'' lasers (those of wavelength $\leqslant 2$ μm), there have been many reports of the scaling of the ''SBS'' amplitude with the pump laser intensity, I_{pump}, but there are no threshold results and no experiments which accessed the linear regime prior to 1993.

This is of more than historical concern, however, as a definitive identification of SBS is very difficult in the nonuniform, flowing and evolving plasmas typically studied using short-wavelength lasers. In particular, for reasons discussed elsewhere,[20] one cannot identify SBS in such plasmas from the frequency shift of the observed light or from a nonlinear dependence of the signal on the pump laser intensity. This leaves one with the option of observing the scaling of the SBS onset and comparing it with theoretical predictions. The short-wavelength experiments, with one exception,[21] have been only convectively unstable for SBS. In particular, they do not exceed the damping threshold for absolute instability. In contrast, they nearly always exceed the damping threshold for convective amplification,[22] as is illustrated in Fig. 1. The convective and absolute damping thresholds are

$$\gamma_0^2>\Gamma_1\Gamma_s \quad \text{and} \quad \gamma_0>\frac{1}{2}\left\{\Gamma_1\sqrt{\frac{v_s}{v_1}}+\Gamma_s\sqrt{\frac{v_1}{v_s}}\right\}, \tag{1}$$

respectively, in which Γ_1 and Γ_s are the amplitude damping rates of the scattered light wave and the acoustic wave, respectively, and the group velocities of the scattered-light wave and the ion wave are v_1 and v_s, respectively. The growth rate in a homogeneous plasma in the absence of damping is γ_0, given by

$$\gamma_0=\frac{|v_{\text{os}}k|}{4}\sqrt{\frac{\omega_{pi}^2}{\omega_1 c_s k}}, \tag{2}$$

in which the oscillating velocity in the field of the pump is v_{os}, the ion plasma frequency is ω_{pi}, and the scattered-light frequency is ω_1.

A further complication in comparison of experiment and theory is introduced by the structure in the laser beam, which implies that γ_0 varies across the beam and that the overall behavior of the instability is some sort of statistical average. The advent of random phase plates, which produce a known distribution of intensities in the laser beam, has improved matters. It has permitted the development of statistical theories[23–27] of the onset of SBS. Under typical circumstances, one anticipates a very rapid, supraexponential onset of SBS with increasing laser intensity. Recent experimental work has identified SBS and tested SBS theory by observing the scaling of the SBS onset and comparing it with theoretical predictions. The theory of the convective amplification of SBS in a homogeneous plasma has been confirmed (to within factors of ~ 2) by varying the length of the laser speckles.[28,29] The theory of convective amplification of SBS in an inhomogeneous plasma with a velocity gradient has been confirmed in two cases. In the first,[30] the onset and spectrum of SBS was observed in plasmas having gentle velocity gradients produced by the ablation and recoil of a thin target. In the second,[27] the onset and spectrum of SBS was observed in plasmas produced by exploding a thin foil. Some of this work provided further data regarding the acoustic noise, obtained at pump intensities below the onset intensity for SBS. Such data are presented and discussed below.

III. EVIDENCE REGARDING ACOUSTIC NOISE

A. Review of prior work

By acoustic noise we mean the ambient level of acoustic fluctuations in the plasma. This is the level of fluctuations from which SBS grows. The noise is presumed to be broadly distributed in **k** space, although at this writing the **k** spectrum remains primarily a subject for future work. To measure this noise level, one should examine a plasma of density well below $n_c/4$, so that two plasmon decay and parametric decay cannot contribute to the acoustic fluctuations. To measure the noise level with laser scattering, the intensity of the probe laser must not excite SBS. Ideally, the peak intensity of the probe should be less than the damping threshold for convective SBS. It is sufficient, however, that this intensity be below the absolute damping threshold and that the convective amplification (accounting for hot spots) be negligible, because, throughout the extensive literature on the subject, scattering instabilities have been observed only when one of these conditions is violated.

The first published evidence that the acoustic noise may be enhanced is found in a paper[31] by Baldis *et al.* This paper reports an experiment in which a preformed, exploding-foil plasma is irradiated by a 10 ps pump laser pulse, and the reflected signal is measured for a sequence of pump intensities.[32] Theoretical calculations, based on a companion paper,[33] are compared with the data. These show that, when the SBS amplification is small, the scattered signal is about five orders of magnitude above the scattering anticipated from thermal noise. Sources of acoustic noise considered and not rejected in this work include the generation of ion turbulence in consequence of either stimulated Raman scattering or intense local heating by the pump.

The next published evidence suggesting that noise levels are enhanced is found in the experiment[34] of Baton *et al.* In this case, a preformed, exploding-foil plasma was irradiated with a 1 ps pump laser pulse, and the reflected signal was measured for a sequence of pump laser intensities. The data are interpreted to suggest that an enhanced noise source which depends on the pump laser intensity is present. However, as is discussed in the paper, the analysis does not include the impact of hot spots in the pump laser on the behavior of the instability. Such hot spots have subsequently[23,25,27] been found to have significant effects. The source of acoustic noise suggested in this work is again the generation of ion turbulence in consequence of stimulated Raman scattering.

In the meantime, an experiment (the ''Bradley'' experiment) was designed to access the linear regime of stimulated scattering (as the thesis research of Dr. Keith S. Bradley).[35] In particular, it satisfied two conditions for the validity of the standard linear theory, $\gamma_0 \ll \omega$ and $v_{os} \ll v_e$. Here v_e is the electron thermal velocity, given by $\sqrt{T_e/m}$, where the electron temperature and mass are T_e and m, respectively. The key to satisfying these constraints, which had not been possible in many prior experiments, was to use a plasma whose velocity gradient was small enough that measurable gain could be obtained with a comparatively low I_{pump}. This experiment used eight beams of the Nova laser[36] to explode a thin, titanium foil for 2 ns before irradiating the resulting plasma with a pump beam.

The implications of the Bradley experiment for acoustic noise were discussed in a paper[37] by Drake *et al.* In the case analyzed, I_{pump} increased from 4×10^{13} W/cm^2 at the start to 4×10^{14} W/cm^2 at the end. Even at the end of this pulse, the calculated convective amplification was negligible. At the start of the laser pulse, the scattering was five orders of magnitude higher than one would have expected to observe (from thermal noise). The initial signal levels are evidence of large acoustic noise levels having a broad angular spectrum. (The later-time data could indicate that the intense signal in the backscatter direction somehow develops at the expense of the noise level in other directions, consistent with some other more-recent observations.[38])

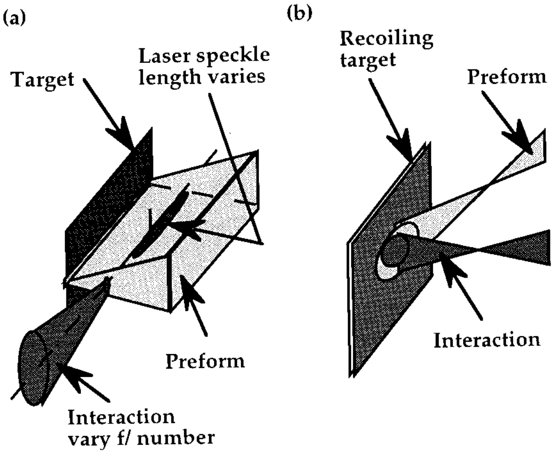

FIG. 2. The geometry of two experiments which detected the onset of SBS. (a) An experiment in which an interaction beam of variable f/number probed a finite-length, quasi-homogeneous plasma produced by a line focus. (b) An experiment in which a thin target that did not burn through produced a plasma with a small velocity gradient by recoiling, allowing SBS to be driven in an inhomogeneous plasma.

B. Evidence from the SBS onset experiments

There are several reasons why further evidence regarding the acoustic noise is worth reporting. First, we do not understand what is responsible for the observations just described and thus it is worthwhile to develop a phenomenological account of the occurrence of enhanced noise. Second, there is very little evidence regarding the time dependence of the scattering when SBS is thought to be negligible. Third, there is little evidence regarding the spectrum of such scattering. Fourth, evidence regarding noise levels in the absence of stimulated Raman scattering is useful, as some of the prior investigators suggested that stimulated Raman scattering might be responsible for the observed noise. These reasons motivate the data we present here.

We obtained further evidence regarding the acoustic noise in two experiments which observed the onset of SBS.[28,30] Details of these experiments are given in the references cited. They were both performed using the Trident laser system at Los Alamos National Laboratory.[39] The data varied reproducibly with conditions, as was confirmed by repeated experimentation for all of the data discussed here. The scattered light was measured using a streaked spectrometer system. Its wavelength resolution of 1 Å was obtained at the expense of a spreading of the data within the spectrometer by 230 ps in time. The spectrum was measured from +10 Å to −20 Å relative to 527 nm, but only the region over which signals were observed is shown in the plots below. The laser pulses were measured in both of these experiments using a fast photodiode. For the comparisons with the scattered-light data below, these signals were then convolved with the (much slower) time response of the streaked spectrometer system. Figure 2 shows the geometry of these two experiments. Each of them produced a preformed plasma, irradiated it with a pump laser, and measured the backscatter of the pump. In the following, the pump intensity I_{pump} is the average of the laser energy over the full width at half maxi-

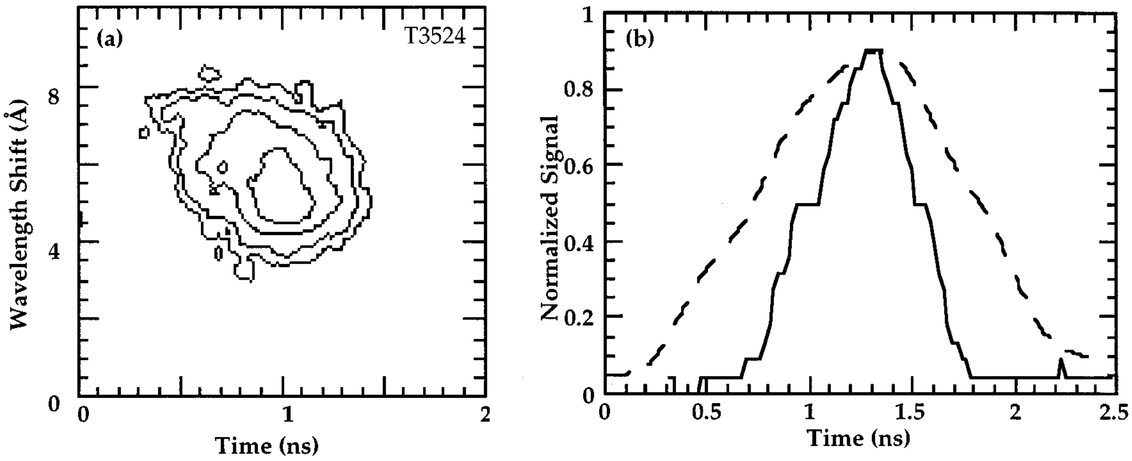

FIG. 3. Scattered-light data for the experiment of Fig. 2(a), for the case of low pump intensity. (a) The spectral intensity of the scattered light. The contours show 12.5%, 50%, and 75% of maximum intensity. (b) The wavelength-integrated time dependence of the scattered light (solid line), compared with the laser pulse as measured by the photodiode (dash-dash-dot line). The data are normalized to have the same maximum.

mum (FWHM) of the laser pulse in time and space. In the case of Fig. 2(a), the pump laser was introduced along the line focus of the preforming laser beam so as to irradiate a nearly homogeneous plasma. In the case of Fig. 2(b), the pump laser was introduced along the velocity gradient formed by the irradiation and recoil of a thin target.

Figure 3 shows data from the case of Fig. 2(a) at $I_{\text{pump}}=4\times 10^{14}$ W/cm^2. The reflectivity in this case was $<$ 0.025%, more that 40 times smaller than the reflectivity observed at $I_{\text{pump}}=5\times 10^{14}$ W/cm^2. In Fig. 3(b), the duration of the scattered light signal is seen to be significantly shorter than that of the laser pulse. (Though it is longer than the duration observed[28] at higher I_{pump}.) This indicates that we are not observing the noise level and that the reflectivity from noise is $<$0.003%. The density probed here is $\sim 0.05 n_c$, where n_c is the critical density of the pump. Using the same instrumental setup, we also did not detect noise from this density in the other experiment discussed next. Although the data of Fig. 3(b) are aligned in time for clarity, calibration of the timing shows that the signal occurs at 260±220 ps after (but perhaps very near) the peak of the laser pulse. This is in contrast to the observed behavior at higher intensity, for which the signal occurs early in the laser pulse. We are apparently observing weak SBS, amplified in a few hot spots, for I_{pump} near the critical intensity.

Figure 4 shows contours of the spectral intensity of the scattered light for three experiments in the geometry of Fig. 2(b). One can see a transition from a slowly varying signal in Fig. 4(a) to much more structured behavior, at higher I_{pump}, in Fig. 4(c). We interpret these spectra with reference to hydrodynamic simulations that connect I_{pump}, n, u, c_s, and thus wavelength shift. In all these cases, stimulated Raman scattering is definitely below threshold, so it cannot be responsible for the observed behavior. The spectra in Fig. 4 show signals from the highest densities reached by the laser light before it is calculated to become strongly absorbed. This is expected because the scattering from noise increases with density as does the SBS growth rate.

In Figs. 5–7, we compare the time dependence of the backscattered signal with the time dependence of the laser pulse for the experiments of Fig. 4. The dashed curves in these figures show the laser pulses. These increase with time

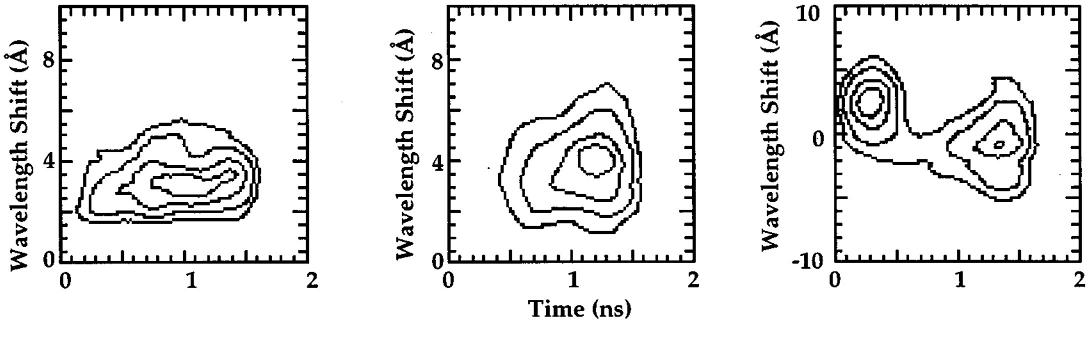

FIG. 4. The spectral intensity of the scattered light for the experiment of Fig. 2(b), for three cases. The contours show 12.5%, 25%, 50%, and 75% of maximum intensity. I_{pump} (W/cm^2) and the maximum spectra intensity in the data. (W cm^{-2} nm^{-1}) are (a) 5.7×10^{12}, 7.1×10^{10}, (b) 1.4×10^{13}, 7.1×10^{11}, and (c) 7.3×10^{13}, 1.4×10^{13}.

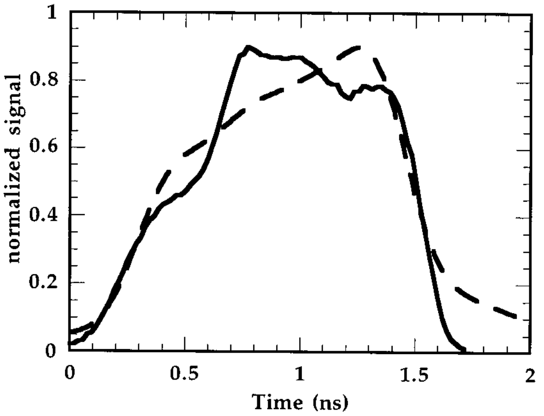

FIG. 5. The wavelength-integrated time dependence of the scattered light (solid line) for the case of Fig. 4(a) is compared with the laser pulse shape (dashed line).

in each case, which was necessary in order to obtain low pump intensities using the Trident laser system as configured for this experiment. Figure 5 corresponds to Fig. 4(a). The two curves have been normalized in amplitude to have approximately the same FWHM. The scattered light shows the approximate time dependence of the laser pulse, as one would expect for scattering from noise. In this case I_{pump} is below the threshold for SBS imposed by collisional damping and in addition the anticipated SBS amplification, including the effect of the hot spots present in the pump, is negligible. The gain for filamentation in the hot spots is also negligible. As is typical for weak signals obtained using a streak camera, one cannot rule out factor-of-2 variations in the signal relative to the laser pulse. The point here is that we do not see the deviance of an order of magnitude or more which would be characteristic of the onset of an instability that is far from saturation, and which we did observe once the anticipated SBS amplification became significant.

Figure 6 shows the case of Fig. 4(b), for which I_{pump} is just above the damping threshold. The two curves have been normalized to have approximately the same FWHM. Here the shape of the scattered light signal deviates further from the shape of the laser pulse, and might correspond to as much as a fourfold amplification by SBS near the end of the pump pulse. This is plausible, as the SBS amplification is expected to increase nonlinearly as the laser intensity increases throughout the laser pulse. The observations at larger I_{pump}, discussed next, lend support to this interpretation.

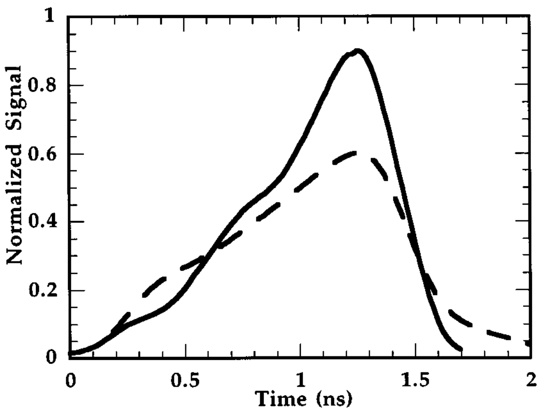

FIG. 6. The wavelength-integrated time dependence of the scattered light (solid line) for the case of Fig. 4(b) is compared with the laser pulse shape (dashed line).

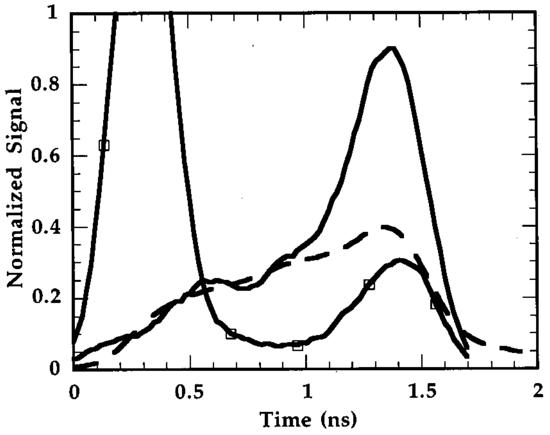

FIG. 7. The time dependence of the scattered light for the case of Fig. 4(c) is compared with the laser pulse shape (dashed line). Data (solid line) are shown for two, 1 Å wide wavelength bands centered at -3 Å and at $+4$ Å.

In Fig. 7, corresponding to Fig. 4(c), the scattered-light signals definitely deviate from the shape of the laser pulse. It is clear in Fig. 4(c) that the scattered light at this pump intensity shows a response having two very different time dependences. Accordingly, Fig. 7 shows the scattered-light signals in two wavelength bands (-3 ± 0.5 Å and $+4\pm0.5$ Å, as indicated), plotted using the same normalization. The wavelength shifts are relative to the 527 nm wavelength of the pump. The laser pulse is normalized to overlap with the early time behavior of the signal at -3 Å. The signal at -3 Å increases, late in time, more rapidly than the laser pulse. The observed behavior is similar to that seen, at longer wavelengths, in Fig. 6, for smaller I_{pump}. This difference is reasonable, because the shorter wavelengths observed in Fig. 4(c) correspond to lower densities in the plasma, where γ_0 is smaller at any given I_{pump}. Here again, the increase of the laser intensity toward the end of the laser pulse can plausibly produce observable SBS amplification. We note that the onset of SBS is anticipated to be extremely rapid: The amplification is predicted to have a supraexponential dependence on the laser intensity. The actual onset might be more abrupt than Fig. 7 shows, because of the 230 ps time resolution of the measurement.

The signal at $+4$ Å in Fig. 7 deviates from the shape of the laser pulse both initially and again later. The abrupt onset at the start of the laser pulse is like that seen at all higher values of I_{pump}. We have elsewhere[30] attributed this to the onset of SBS as the average laser intensity increases above its critical value for some range of scattered wavelengths. The return of signal at this wavelength toward the end of the laser pulse is real (i.e., it is not due to signal from shorter wavelengths as distributed by the point-response properties of the streak camera). An evaluation of its significance, however, would require a more detailed study of the response of the plasma in this regime of I_{pump}.

C. Discussion of the acoustic noise observations

The evidence of Figs. 4(a), 5, and the prior work has three of the four characteristics one would expect from enhanced acoustic noise. First, the scattered signal has the approximate duration and time dependence of the laser pulse, as expected for scattering from noise. Second, the reflectivity is quite large (10^{-3} to 10^{-4}), about 10^5 times the reflectivity one would see from thermal noise. Third, the wavelength of the observed scattering is as expected for downshifted scattering from acoustic noise in the plasmas studied here. However, we do not observe the upshifted scattering which we would also expect, as is discussed next.

The caveat which applies to much of this evidence regarding acoustic noise is that one would expect the noise to be relatively isotropic. There is some evidence for this in the initial distribution of the signal in the Bradley experiment. The existence of isotropic noise would imply, however, that one ought to see equally intense upshifted and downshifted scattering. In the cases of Figs. 4–7, we definitely could have seen such scattering and do not. In other cases,[31,34,37] the velocity gradient or the laser bandwidth complicate the issue, but nonetheless it appears that the upshifted (or anti-Stokes) signal was not present. All these plasmas are nonuniform and effects such as electron drifts could lead to strong asymmetries in the ion wave damping. In contrast to these results for acoustic noise, both upshifted and downshifted signals were seen in experiments which probed the ion plasma wave regime.[40,41] In this case the level of the noise appeared to be no more that 100 times thermal. Until further study, it remains unclear what the distribution of the noise is or why.

These observations of scattering from acoustic waves differ markedly from comparable studies of scattering from Langmuir waves, which becomes stimulated Raman scattering when above the damping threshold. The reduction of such scattering to thermal levels was documented[42] in the late 1980s for nanosecond-time scale experiments. More recently, the technique of using a picosecond pump to irradiate a preformed plasma was used[43] by Rousseaux *et al.* to accomplish a very clear experiment, even though the instrumentation was not quite sensitive enough to detect scattering from thermal noise. As I_{pump} decreased, the observed scattering decreased more than seven orders of magnitude, in excellent agreement with theory on the assumption that the Langmuir waves were growing from thermal noise levels. Whatever mechanism accounts for the enhanced levels of acoustic noise is evidently not effective for Langmuir waves.

In addition, it has recently become more clear from a theoretical point of view why the acoustic noise level may very often be far above thermal. If one focuses one's attention narrowly on the waves having wave numbers of order the pump wave number, one may expect the noise to be thermal, as such waves typically have frequencies of order 10^{12} s^{-1} and damping times of < 100 ps, so that any such noise, perhaps produced during plasma formation, will die out in a few hundred ps. However, the plasma also contains structures with wavelengths of 0.1 to 1 times the plasma size, produced during and perhaps after the plasma formation. (Whether by experimental nonuniformities, hydrodynamic instabilities, thermal instabilities, or other mechanisms is unimportant here but is a topic for future research.) In typical cases, these structures have wave numbers below 10^3 cm^{-1}, frequencies below 10^{10} s^{-1}, and damping times above 10 ns. They outlive the typical experiment, and they have consequences.

In particular, these structures, viewed as very long-wavelength waves, will couple with one another to drive shorter-wavelength oscillations. Such mode coupling is nonresonant, but nonetheless it has been shown that long-wavelength modulations at the 1% level can couple so as to produce acoustic noise that is far above thermal levels throughout the SBS range of wave numbers.[5] Such behavior, in which long-wavelength fluctuations drive up the noise throughout the acoustic wave phase space by mode coupling, could easily turn out to be ubiquitous in plasma systems.

Other phenomena may also contribute to enhanced acoustic noise. If the hydrodynamic behavior is such as to produce shock waves[44] or ion jets,[45] these will damp by producing acoustic noise but may nonetheless have the long lifetimes required to affect an entire experiment. Filamentation and Langmuir collapse, in contrast, cannot be effective until they have had time to develop but could in the course of an experiment become a source of acoustic noise.

IV. CONCLUSION

It is thus clear in evidence from a number of experiments that laser plasmas often have a large acoustic noise level. It is further clear that in at least some cases this noise cannot arise in consequence of stimulated Raman scattering. One promising hypothesis is that the noise may arise from the nonresonant mode coupling of very long-wavelength hydrodynamic structures in the plasma. This source of acoustic noise is not unique to laser plasmas, as long-wavelength structures are present in nearly all plasmas. Thus, these data lead us to suggest that large acoustic noise levels may be ubiquitous in plasmas. The laser-plasma environment offers the potential to undertake systematic studies of the spectrum and scaling of such noise, so as to determine its origin, which would provide the incentive for more theoretical work.

The observed noise may have some impact on the behavior of SBS. It certainly impacts the onset of SBS, which cannot originate at thermal levels. The noise may increase the effective damping of driven ion waves, and if large enough could invalidate the three-wave description used in the standard theory of SBS. However, the success of recent experiments in obtaining (factor of 2) agreement with the standard theory suggests that this is not the case. It remains to be seen whether the noise plays a role in the saturation dynamics of SBS, which are still not well understood.

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