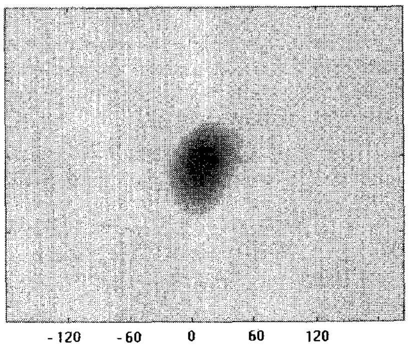
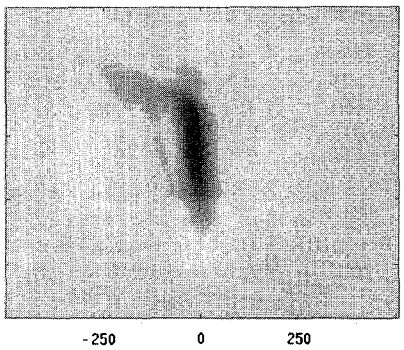


JThA3 Fig. 1 Spatial profile of the guided Ti: sapphire laser pulse at the output of the plasma waveguide. N_2O at 100 torr, size is 50 microns FWHM.



JThA3 Fig. 2 PG FROG trace of the pulse produced by Ti:sapphire system. Corresponding pulse duration is 80 fs FWHM.

pulse is shown in Fig. 2. The pulse duration is measured to be 80 fs FWHM. Detailed phase and amplitude information can be extracted by use of algorithms discussed in Ref. 4.

In conclusion, this experiment demonstrates the ability to propagate an intense femtosecond pulse over several centimeters in a preformed plasma waveguide. Applications of this technique include soft x-ray generation, plasma wakefield particle acceleration, and studies of laser-plasma interaction at relativistic laser intensities.

1. C. G. Durfee III, T. R. Clark, H. M. Milchberg, J. Opt. Soc. Am. B **13**, 59 (1996).
2. C. G. Durfee III, J. Lynch, H. M. Milchberg, Phys. Rev. E **51**, 2368 (1995).
3. D. J. Kane, R. Trebino, Opt. Lett. **18**, 825 (1993).
4. K. W. DeLong, D. N. Fittinghoff, R. Trebino, B. Kohler, K. Wilson, Opt. Lett. **19**, 2152 (1994).

JThA4 **9:15 am**

Temporal characterization of a self-modulated laser wakefield accelerator

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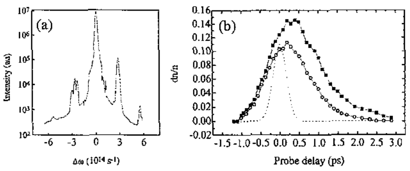
Because electrostatic fields in a plasma wave ($E \geq 100$ GV/m) can exceed those in conventional RF linacs, plasma-based accelerators can potentially offer a compact method for accelerating high energy electrons. Of the several methods for driving large amplitude plasma waves, the self-modulated laser wakefield accelerator (SM-LWFA) has recently demonstrated electron acceleration to energies in excess of 10 MeV.[1] In this paper we demonstrate a femtosecond pump-probe experiment based on forward, collective Thomson scattering[2] for characterization of the amplitude, growth, and decay rate of a self-modulated wakefield. Measurement of the plasma wake temporal structure is of importance for understanding the growth dynamics of plasma wave instabilities and testing recently developed 2D particle-in-cell simulations of laser plasma interactions.

In these experiments, a $\lambda = 1$ μm, $\tau =$ 400-fs laser pulse was focused onto a supersonic helium gas jet whose neutral density varied linearly with backing pressure. To probe the lifetime of the plasma wave, a small portion (20%) of the infrared laser pulse was split off, frequency doubled, and then made to copropagate with the infrared pump pulse. Forward scattered light from the probe pulse was collected on axis, passed through a polarizer to suppress scattered pump light, and measured with a prism spectrometer. When the peak power of the IR pump pulse ($P \geq 1$ TW) is near the critical power for relativistic self-focusing $P_c = 17(\omega_o^2/\omega_p^2)$ GW, a collimated beam of 2 MeV electrons with a transverse emittance of 1 mm-mrad is emitted in the laser propagation direction.[3]

When the green probe pulse propagates through the plasma, collective Thomson scattering from the relativistic plasma wave causes multiple side bands to appear in the spectrum of the forward scattered probe light. For $P = 3$ TW and a backing pressure of 100 psi, Fig. 1a shows the appearance of first- and second-order Thomson scattered satellites, which are separated by the plasma frequency $\omega_p = 2.7 \times 10^{14}$ s^{-1}. The amplitude of the plasma wave determined from both the absolute ($\delta n/n =$ 0.08) and relative scattering efficiency ($\delta n/n =$ 0.1) of the first-order Thomson side bands are in reasonable agreement. From the second-order satellites, the amplitude of the second harmonic of the plasma wave is $\delta n_2/n = 0.01$.

By measuring Thomson scattering from the probe pulse as a function of the delay between the pump and probe, the temporal envelope of the wakefield oscillations can be recorded. Figure 1b shows the plasma wave amplitude as



JThA4 Fig. 1 a) Spectrum of the Thomson scattered probe light for a helium backing pressure of 100 psi, $P = 3$ TW, and $\Delta t = 0$. b) Amplitude of the plasma wave determined from the scattering efficiency of the Stokes (filled squares) and anti-Stokes (open circles) satellites as a function of delay for a helium backing pressure of 180 psi. The dotted curve indicates the 1.5-TW, 400-fs pump pulse.

function of the probe delay time for a helium backing pressure of 180 psi. The plasma wave is measured to have a peak amplitude $\delta n/n =$ 0.1, which corresponds to a maximum longitudinal field of $E = 56$ GV/m for a cold, non-relativistic fluid. Under the current tight focusing conditions, the maximum radial electric field is $E_r = 2E_z/k_p r_0 = 0.2E_z$. Figure 1b shows that the wakefield amplitude maximizes at the end of the pump pulse ($\Delta t = 300 \pm 100$ fs) and lasts for approximately 2 ps longer.

The measured exponential rise time (4.0 ps^{-1}) of the wakefield is in agreement with that expected from the growth of the forward Raman scattering (FRS) instability. The onset of FRS is coincident the development of an ionization-induced blue-shifted spectral wing on the probe pulse, suggesting that the FRS is seeded by a ionization front noise source.[7] Since the total energy of the accelerated electron beam (~1 mJ) is approximately equal to the energy in the plasma wave, the measured exponential decay rate of the wakefield (1.9 ps^{-1}) is consistent with nonlinear Landau damping of trapped electrons or beam loading of the plasma wave.

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1. For a recent review see E. Esarey *et al.*, IEEE. Trans. on Plasma Sci. **24**, 252 (1996).
2. S. P. LeBlanc *et al.*, to be published in Phys. Rev. Lett.; A. Ting *et al.*, to be published in Phys. Rev. Lett.
3. D. Umstadter *et al.*, Science **273**, 472 (1996).
4. C. D. Decker *et al.*, Phys. Plasmas **3**, 1360 (1996).

JThA5 (Invited) **9:30 am**

Constraints on laser-driven accelerators for a high-energy linear collider

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Lasers may have a significant future role in accelerators. Applications include photocathodes, beam phase space manipulation, photon colliders, short pulse generation, and acceleration. The most challenging of these applications and the one with the largest potential impact to high-energy physics, is the development of a linear collider driven by free-space laser or laser-plasma acceleration. Over the last two decades much theoretical and experimental research has been done on the acceleration of particles by lasers. Progress has been made in the theoretical understanding of the complicated phenomena associated with the interaction of lasers and plasmas, in numerical modeling of such phenomena, in acceleration of particles to 100 MeV energies, and in the development of lasers.

The analysis will consider a 5 TeV center-of-mass collider. This is well above the 0.5-1.5 GeV energy where the proposed Next Linear Collider, based on conventional technology, is designed to operate. General considerations having to do with luminosity, beamstrahlung (including quantum effects), and wall-plug power will be made. These allow us to derive diverse parame-