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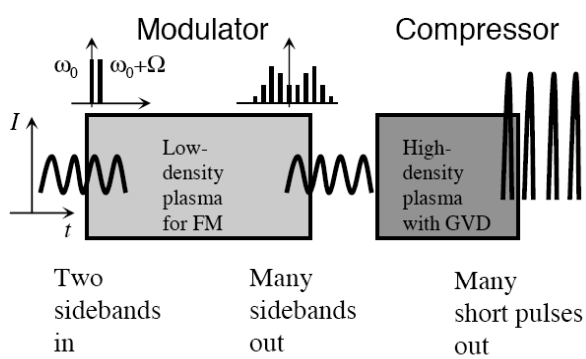
# Accelerating Electrons with Bright Sparks

*A train of ultra-intense radiation spikes can be created and used as an advanced electron accelerator for medical and physics applications*

DENVER, Colorado, Oct. 24, 2005 – A new method to amplify and compress laser power, which uses a plasma of ions and electrons, has been discovered by scientists at the University of Texas. If this method is proven in experiments, it could be applied to construct tabletop electron accelerators for promising applications in medicine and fundamental physics research.

For nearly two decades the standard method for generating high power, ultra-short laser pulses has been chirped-pulse amplification. Recently, a significantly different approach has been proposed by several groups: instead of stretching the pulse in time and preserving its spectral characteristics, to broaden the frequency spectrum of the pulse toward both high and low frequencies (a process known as electromagnetic cascading) and reduce its time duration. This approach has been tested in standard gases for low-power lasers. It cannot, however, be extended to high laser intensities because the gas breaks down.

The new method, to be reported in an invited talk at the 2005 APS Division of Plasma Physics Annual Meeting, shows how to extend electromagnetic cascading and produce ultrahigh laser intensities through the exploitation of the nonlinear properties of a fully ionized plasma.




Schematic of the two-stage cascade compressor. Frequency modulation (FM) occurs in a rarefied plasma, after which the laser sidebands are compressed by means of the large group velocity dispersion (GVD) in a high-density plasma into a train of femtosecond spikes.

Two laser beams traveling in the same direction are directed into a low-density plasma. Their frequencies are slightly detuned from each other, with the frequency difference (like the “beat” between two slightly off-pitch notes on a piano) chosen to efficiently excite many sideband waves. Thus, the low-density plasma acts like a frequency modulator in a radio, converting the incident two waves of the laser beams into a broadband laser pulse with many sidebands.

Next the broadband frequency-modulated laser pulse is sent into a high-density plasma, which acts as a compressor, producing a train of ultra-short, ultra-powerful radiation spikes ("bright sparks"). The spikey pulses are each about 10 to 100 times as intense as the initial laser beam. Compression to petawatt power levels (more than a quadrillion watts) may be possible. (While pulse compression with counter-propagating laser beams had been proposed earlier, the new method with co-propagating beams is much easier to implement experimentally.)

Finally the radiation spikes can create plasma wave "buckets," grabbing and accelerating low-energy electrons up to hundreds of millions of electron volts. These fast electrons could be used for a portable X-ray source in medical applications or for gamma-ray radiography of tiny objects. Because plasma waves can sustain electrical fields that are a thousand times larger than those in conventional particle accelerators, this new method could also lead to smaller and more affordable particle colliders for high-energy physics studies.

Plasma beat-wave accelerators, another promising method for particle acceleration currently under study, will be enhanced by this new method, which takes advantage of a single high-energy pulse and its down-shifted component created by a solid state Raman frequency shifter (a nonlinear $Ba(NO_3)_2$ crystal that produces a downshifted frequency component).

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**[FI2.00005]** Compression of laser radiation in plasmas using electromagnetic cascading
Abstract: **http://meetings.aps.org/Meeting/DPP05/Event/34924**
October 25, 2005
Tuesday, 11:30 am–12:00 pm
Invited Session FI2: Plasma-Based Acceleration and Light Sources
Adam's Mark Hotel - Plaza Ballroom EF

**Further information**

Serguei Kalmykov and Gennady Shvets, "Compression of laser radiation in plasmas using electromagnetic cascading," *Physical Review Letters* (2005), volume 94, paper no. 235001.

Research Highlights: "Bright Sparks," *Nature (London)* (2005), volume 436, page 154.