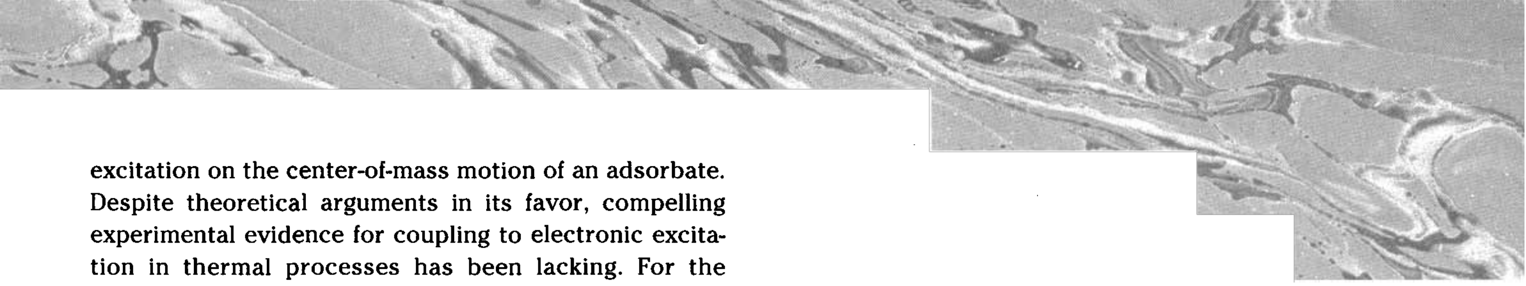

excitation on the center-of-mass motion of an adsorbate. Despite theoretical arguments in its favor, compelling experimental evidence for coupling to electronic excitation in thermal processes has been lacking. For the subpicosecond excitation of the present experiment, the electronic degree of freedom of the substrate is effectively decoupled from the photons. This allows the electronic temperature to rise considerably above that of the lattice for an interval of roughly 1 ps.

With a suitable model of the transient electronic and lattice heating, calculations for the correlation trace can be performed. Part (b) shows the expected behavior in the limiting cases where full equilibrium of the molecular motion with either the electronic or the lattice temperatures of the metal is assumed. The experimental data are clearly incompatible with a mechanism based on lattice heating and demonstrate unambiguously the importance of the electronic channel for desorption. Thus, the nonequilibrium excitation created with femtosecond laser pulses permits an experimental discrimination of electron and photon coupling to the motion of an adsorbate. These studies demonstrate the potential of ultrafast optical techniques in elucidating fundamental problems in the field of surface dynamics.

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SELF-MODELOCKING: ULTIMATE SIMPLICITY IN ULTRASHORT PULSE GENERATION

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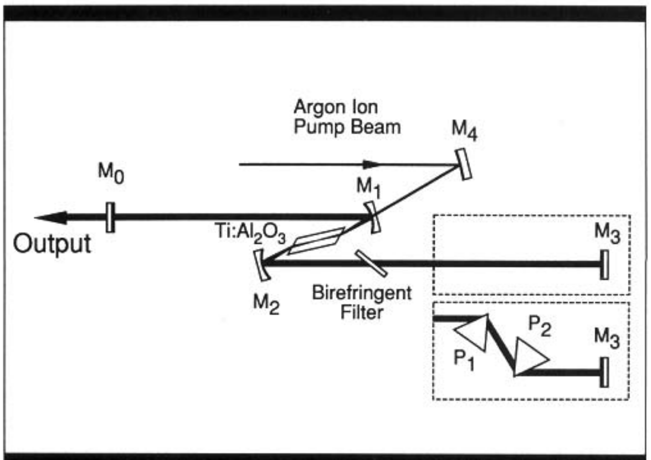
For the past 25 years or so, there have been many sustained research programmes devoted to the study of the techniques by which ultrashort ($\leq 10^{-12}$ s) laser pulses can be generated. Whereas spectral purity can be ensured by constraining the laser to operate on a single axial or longitudinal mode of the resonator, the production of picosecond or shorter pulses demands that many longitudinal resonator modes must be precisely locked in phase by a process that is referred to as modelocking.



Schematic of cavity arrangement of self-modelocked Ti:sapphire laser. The inset shows the intracavity prism pair used for group velocity dispersion compensation (from Ref. 5).

During the mid to late 1980s, the concept of coupled nonlinear cavities was pioneered by Mollenauer and coworkers through their demonstration of the soliton laser.[1] A more generalized manifestation of this scheme—involving both normal (*i.e.*, non-soliton-supporting) and anomalous dispersion fiber or a semiconductor diode amplifier as the nonlinear element of the coupled cavity—has given rise to the technique called coupled-cavity[2] or additive-pulse[3] modelocking. This has been applied to a wide range of laser types and femtosecond pulse generation has been demonstrated. Although the frequency-tunability offered by broadband gain media can be accessed, the requirement to accurately match the "control" nonlinear cavity to the master cavity adds some unwelcome complexity to the practical arrangements.

The 1990s have already provided a significant and exciting advance to modelocking so that the desirable features of femtosecond pulse durations and uncompromised frequency-tunability can be obtained using a much simplified procedure. This approach, first reported at CLEO® '90 for a titanium-sapphire laser, is described as self-modelocking.[4] This designation was chosen because no components were added to the standard laser cavity for the specific purpose of modelocking. Indeed, using the configuration illustrated in the figure, pulses as short as 3 psec could be produced by simply aligning the resonator such that lasing occurred simultyaneously on two transverse modes (usually TEM$_{00}$ TEM$_{05}$).[5] With appropriate group velocity dispersion compensation using a pair of intracavity Brewster-angled prisms, chirp-free pulses having durations around 60 fsec have been produced by this method.[5]

The key evolution and shortening kinetics of the laser pulses are attributable to the resonator and the intensity-dependent optical nonlinearities in the titanium-sapphire gain medium itself. Therefore, the tunability is limited primarily by the reflectivity characteristics of the mirrors used. For example, with two commercially available mirror sets (for Spectra Physics, Model 3900) a typical tuning range is 750-950 nm, where other mirrors can be used for spectral extension to shorter or longer wavelengths if desired. A number of related implementations on this scheme have already been reported. Its practicality is highlighted by the fact that four laser manufacturers can now offer fully-engineered ultrashort-pulse Ti-sapphire laser products that are based on the self-modelocking principle.

As a more comprehensive understanding of self-modelocking becomes established, it is likely that this technique will be applicable to other laser types. In particular, the diode laser pumpable new gain media such as Cr^{3+}:LiSrAlF$_6$ may lead to especially attractive low-phase-noise, reliable, and robust laser systems. Additionally, by combining the attributes of high peak power pulses with the current availability of highly efficient nonlinear crystals (*e.g.*, BBO, LBO) a range of frequency-doubling, frequency mixing, and optical parametric oscillator procedures can be exploited. By this means, the prospect of all solid state sources of coherent femtosecond pulses having wavelengths from the ultraviolet to the mid-infrared becomes very real. As a direct consequence, the opportunities for enlarging the applications potential of such pulses from basic time-domain spectroscopy to the technology of digital optics is likely to grow vigorously during this decade. In this expected growth, the self-modelocking technique will undoubtedly have played a role as an important catalyst in respect of the development of ultrashort pulse laser sources. This surely represents a good return on the simplistic approach.

ACKNOWLEDGEMENT

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BALLISTIC 2D-IMAGING THROUGH TISSUE SCATTERING WALLS

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For earlier cancer diagnosis, it is important to image ultrasmall growths with a size of one millimeter or less. Optical radiation[1-5] offers a new method to image a small tumor hidden inside the human body. Transillumination,[3] a technique using light to image breast cancer, was introduced many years ago. However, the ability to observe this image is severely limited by light scattering that forms the image shadow and contributes to the noise. When photons migrate through a turbid medium, there are three main signal components:[1,4] diffusive (incoherent), ballistic (coherent forward scattered that arrive by traveling over the shortest path), and snake (quasi-coherent photons that arrive within the first δt). When the tumor is too small (~1mm), it may not be observed by the transillumination technique. By adding an ultrafast time gate, the detectability of small tumors located inside the breast can be significantly improved. Time-resolved techniques such as the Kerr effect[6] and holography[7,8] can be used to separate out the ballistic and snake components (least distorted image) from the diffusive component (most image information lost).

Using a 2-D picosecond optical Kerr gate[1,6] imaging system, time-gated 2-D ballistic images of ~100 µm dimension in highly scattering media including a 3.5 mm thick human breast tissue, a 3 mm thick chicken breast tissue, and a 5 cm thick water cell with suspended polystyrene balls have been observed at CCNY. The experimental setup consists of a modelocked Nd:glass laser with 8 ps duration at 1054 nm, a CS$_2$ Kerr shutter, and a 2-D image intensified CCD readout system. The second harmonic 527 nm is used to illuminate the hidden object.

A sequence of measured time-dependent 2D Kerr gate video images of a bar chart placed hidden behind 3.5 mm thick human breast tissue are displayed in the figure. The bars of the test chart (5 line pairs/mm) were illuminated by 8 ps, 527 nm laser pulses. Part (a) displays the image of the test chart in air. Part (b) represents the image pictures obtained from standard transillumination imaging (no time-gate) of the chart behind the tissue sample—no clear image can be observed in any of these cases. Part (c) represents Kerr-gate bar images of the ballistic and snake signals at the gating time of T=0. Clear bar images with dimension of ~0.1 mm (separated by 0.2 mm) can be resolved. As the gating time was delayed by 22 ps, the collected images were gradually broadened and blurred as shown in Part (d).

To use the time gating technique to measure phantoms of ~1 mm dimension in a thick scattering wall such as a 60