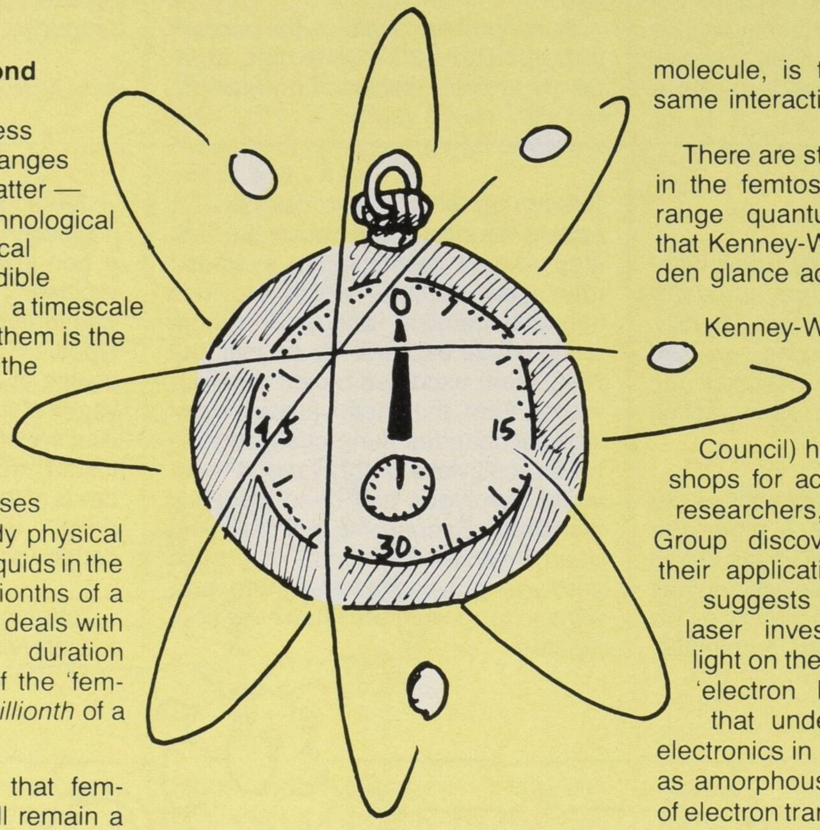
Capsules

Splitting The Femtosecond



Humanity's ability to harness chemical events — the changes that occur constantly in matter — is the foundation of its technological wizardry. But many chemical reactions occur with incredible speed. Observing them in a timescale that lets us make sense of them is the aim of the Laser Group at the University of Toronto.

Dr. Geraldine Kenney-Wallace, one of the members of this group, uses laser spectroscopy to study physical and chemical changes in liquids in the range of picoseconds (trillionths of a second). Her current work deals with laser pulses whose duration approaches the domain of the 'femtosecond' — one *million-billionth* of a second.

Kenney-Wallace thinks that femtosecond laser studies will remain a scientific frontier well into the next century. In this strange world, the frenzied dance of molecules and atoms in a liquid slows to a stately interaction of forces and collisions. Between collisions, perhaps persisting over hundreds of collisions, is a kind of 'molecular memory' determining the liquid's dynamic structure.

During the collisions, energy flows from one molecule to another. Or an electron, scattering through the liquid, can interact with a molecular vibration and suddenly shatter a chemical bond. The fate of 'free radicals,' the energetic fragments of the shattered molecule, is then governed by the same interactive dance.

There are still stranger interactions in the femtosecond range — long-range quantum-mechanical forces that Kenney-Wallace likens to a sudden glance across a crowded room.

Kenney-Wallace's group and NSERC (the Natural Sciences and Engineering Research Council) have held several workshops for academic and industrial researchers, discussing Laser Group discoveries and encouraging their application. Kenney-Wallace suggests that femtosecond laser investigations might shed light on the ultrafast transport of 'electron holes,' the process that underlies modern microelectronics in semiconductors such as amorphous silicon. Another kind of electron transport is believed to be a key element in the function of brain neurotransmitters and color photography. And fast electron transport is at the root of dielectric breakdown, a common problem in the insulation of high-voltage transformers.

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Chips Off a New Block

In the world of communications and computers, silicon reigns supreme as *the* material for making integrated circuits. But now another substance, much faster and more resistant to heat and radiation than silicon, is emerging from the laboratories. Gallium arsenide (GaAs) could be the logical choice for high-speed integrated circuits of the future, and the National Research Council and Bell Northern Research have launched a joint 14.4-million dollar research project, under NRC's Program for Industrial Research Projects (PILP), to develop GaAs technology.

Integrated circuits (IC's) are built on tiny chips of crystalline semiconductive material, usually silicon. A typical chip might contain 50 000 transistors in an area several millimetres square. These devices perform complex electrical functions much as normal circuits do, except faster and at a much lower cost. Gallium arsenide integrated circuits are five to ten times faster than ICs made out of silicon. According to NRC's Dr. James Robar, the energy band structure of the GaAs crystal, which makes its electrons mobile and extremely fast, accounts for the speed in IC's made from gallium arsenide.

This speed, along with gallium arsenide's high heat and radiation tolerance, make GaAs ICs suitable for military and communications applications — for example, circuitry in satellites. But even for applications on Earth, Gallium arsenide's heat resistance is a plus. All integrated circuits give off heat when they operate, and as the density of transistors on the chip increases, temperatures in the IC will rise. Typically, silicon can tolerate temperatures of around 80 degrees Celsius; but gallium arsenide can easily withstand temperatures of 200 degrees Celsius. Thus, computers using GaAs chips can not only compute faster, but also run hotter —