HOW LASERS WORK

Lasers are all around us. There are lasers in your CD player and the CD-ROM in your computer. More powerful lasers can be found in machine shops, where they are used to cut and weld metal. Because laser light travels straight, carpenters use lasers to construct level buildings, while homeowners use them to hang pictures.

The origin of lasers can be traced to Albert Einstein, who first theorized that it was possible to create visible beams of light using a process he called "stimulated emission." Einstein had his brainstorm in 1917, but it was more than 40 years later before someone invented a device based on this process. The scientists who came up with this invention labeled it Light Amplification by Stimulated Emission of Radiation, which was shortened to LASER.

The name describes the method by which all lasers work. "Light Amplification" means that lasers amplify or generate more light. They typically create this additional light by stimulating atoms with electromagnetic radiation, a process known as "Stimulated Emission of Radiation." Visible light, radio waves, microwaves, infrared, ultraviolet, X-ray and gamma rays are all types of electromagnetic radiation. The color of light that is amplified is fixed by the particular atom involved in the process.

The light produced by a laser is different from ordinary light. Most notably, laser light stays in a small beam instead of spreading out like regular light. Laser light can do this because each beam is only one color and all the waves are produced in phase.

Ultraviolet wiggler

Aligning optic system

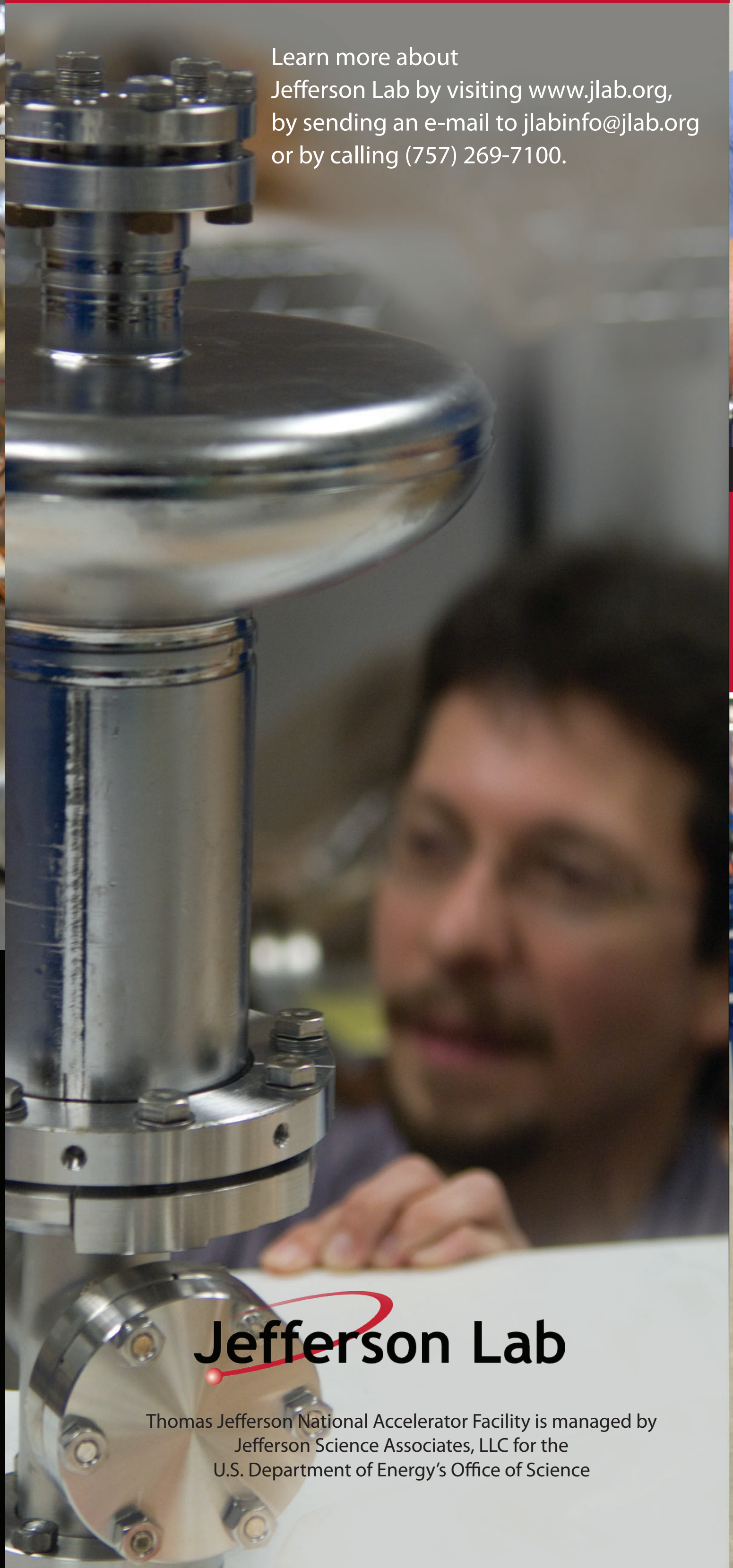
SPECIFICATIONS

Wavelength range (IR)	1-14µm
Power/pulse*	120 µJ
Pulse repetition frequency	Up to 75 MHz
Pulse length	200-1100 fs FWHM
Maximum average power	>10 kW

Wavelength range (UV/VIS)	250-1000 nm
Power/pulse	20 µJ
Pulse repetition frequency	Up to 75 MHz
Pulse length	300-1700 fs FWHM
Maximum average power	>1 kW

The Jefferson Lab FEL is a sub-picosecond, tunable light source covering the range from 250 nanometers in the ultraviolet to 14 microns in the mid-infrared, with pulse energies up to 300 microJoules, and at repetition rates up to 75 megahertz. Not all parameters can be satisfied simultaneously, but average powers in excess of 10 kilowatts have been demonstrated in the infrared.

WANT TO KNOW MORE?



Learn more about Jefferson Lab by visiting www.jlab.org, by sending an e-mail to jlabinfo@jlab.org or by calling (757) 269-7100.

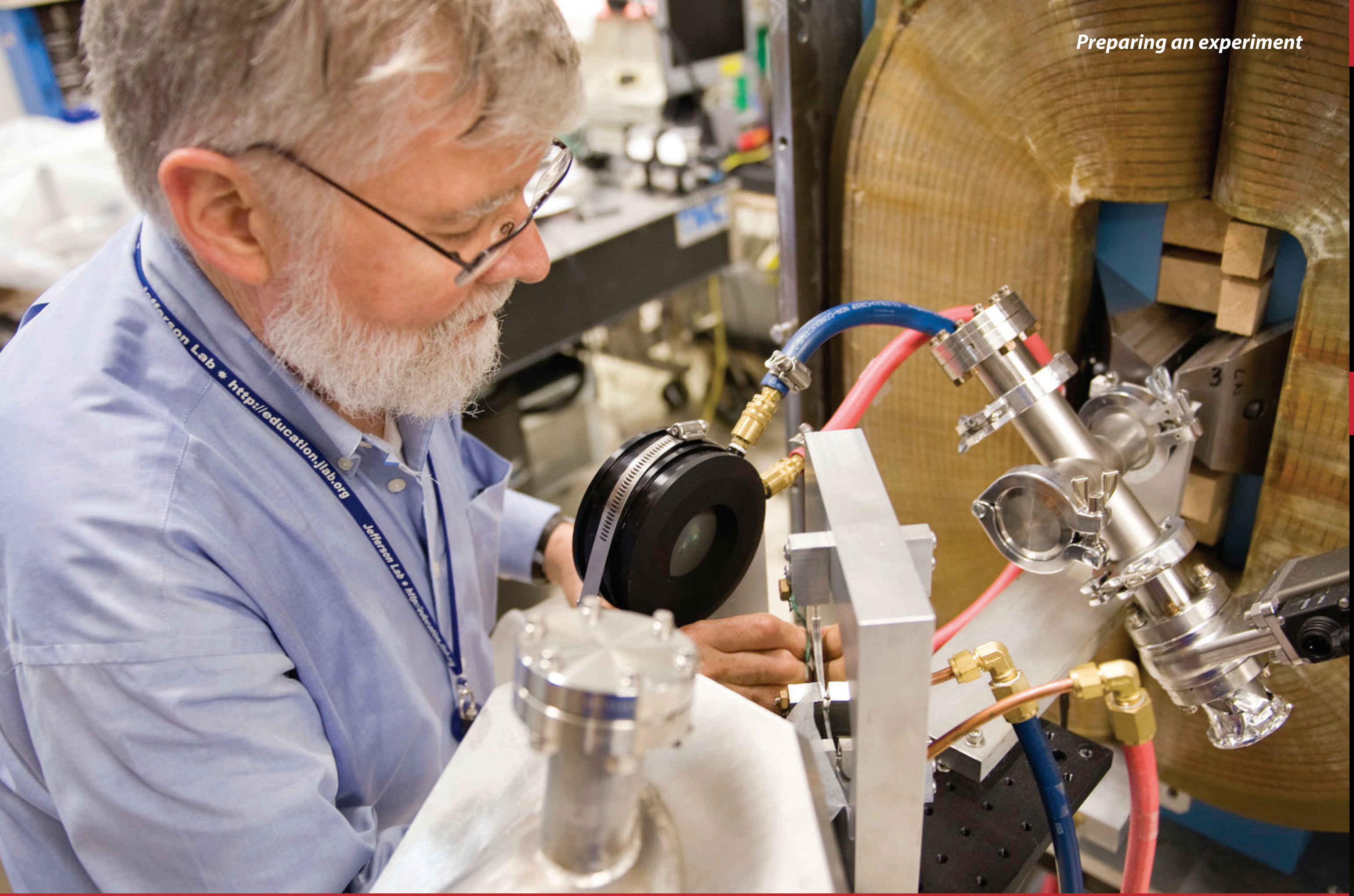
Jefferson Lab

Thomas Jefferson National Accelerator Facility is managed by Jefferson Science Associates, LLC for the U.S. Department of Energy's Office of Science

THOMAS JEFFERSON NATIONAL ACCELERATOR FACILITY

FREE-ELECTRON LASER

FEL magnets



Preparing an experiment

ABOUT THE FEL

Thomas Jefferson National Accelerator Facility is a U.S. Department of Energy national laboratory. The lab's primary mission is nuclear physics research, but a derivative mission is the development and use of free-electron lasers based on the lab's expertise in superconducting radiofrequency accelerators. This led to the development of the lab's Free-Electron Laser, the world's most-powerful tunable laser.

Jefferson Lab's Free-Electron Laser uses electrons to produce laser light. The electrons are energized using the lab's superconducting accelerator technology and then steered into a wiggler. The wiggler is a device that uses magnetic fields to shake the electrons, forcing them to release some of their energy as photons (light). As in a conventional laser, the photons are bounced between two mirrors and emitted as a coherent beam of light.

Operators can adjust the wavelength of the Free-Electron Laser's emitted light by increasing or decreasing the energy of the electrons in the accelerator or the amount of shaking in the wiggler. The light can be tuned to precise colors or wavelengths because the electrons are freed of atoms, thus the name free-electron laser. Jefferson Lab's FEL has significant advantages compared to conventional lasers, making it possible, for instance, to produce intensely powerful light in brief bursts with extreme precision. The lack of a conventional lasing medium also allows the Free-Electron Laser to operate at very high power levels without the cavity overheating.

The uniqueness of Jefferson Lab's Free-Electron Laser also stems from what it does with the electrons. It generates the electrons' energy and then recovers it using a superconducting energy-recovering linac, or ERL. This linear accelerator is a smaller, higher-current cousin of Jefferson Lab's huge electron accelerator. Jefferson Lab's ERL-driven FEL is the first of a new generation of accelerator-based light sources in which each electron circulates only once rather than being stored as it would be in a typical synchrotron light source. Each electron's energy is recovered and almost immediately imparted to another electron in the ERL.

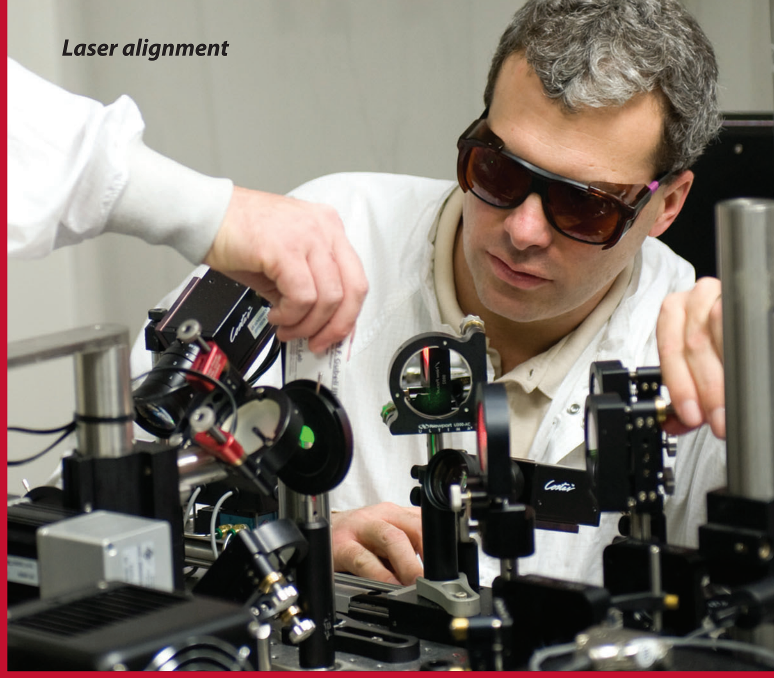
FEL APPLICATIONS

Research with Jefferson Lab's Free-Electron Laser could transform our nation's energy use, making it cleaner and more efficient. This will happen in two ways: first by allowing us to make novel nano- and other materials, with applications as diverse as solar energy conversion and low-emission power plants; and secondly by allowing us to measure the properties of these novel materials. The continued development of programs to produce new light sources will further enhance these research efforts.

LASER FACTS

Laser light is very different from normal light and has the following properties:

- The light is monochromatic. It contains one specific wavelength (color) of light.
- The light is coherent. It is organized so that each photon moves in step with the others.
- The light is directional and can be sharply focused. A flashlight bulb, on the other hand, releases light in many directions, and the light becomes weak and diffuse.



Laser alignment

Exploring laser liposuction