A New Approach to Ultrafast Laser Technology: Integrated Software Design

In making ultrafast laser technology practical and easy to use, Raydiance has focused great efforts on reducing the form factor and cost of the technology while making the hardware itself more robust. However, the real "aha" moment came when the Raydiance team realized it would marry the revolutionary computing and software technologies of the last century to the ultimate frontier technology of this century—photonics. By integrating software control into the system, from high level user commands all the way down to discrete hardware component control, Raydiance has enabled a technology that has the potential to unleash a wealth of applications. Scientists and engineers of varied backgrounds—not just those who work with lasers—are able to realize the power of ultrashort pulses of light in developing new ideas and products.

RayOS™ – Software-Enabled Operation

Raydiance has designed its ultrafast laser platform—the Raydiance Discovery™ System—around a proprietary software architecture named RayOS. All aspects of control, monitoring, sequencing, and safety are under software control. Unlike traditional laser systems in which computer control is an afterthought to manufacturing or "added on" by the user, the Raydiance platform was built with software control as an integral part of the infrastructure.

The system architecture is designed to allow the laser to be run autonomously; no user intervention is necessary except through the LabVIEW-based user interface *(**Figure 1**)*, which is presented on a laptop. The laptop is connected to the laser via an industry-standard Ethernet connection and TCP/IP protocols. And while the laptop is employed as a user friendly graphical interface, all system control computations are done independently by an embedded processor in the laser box.

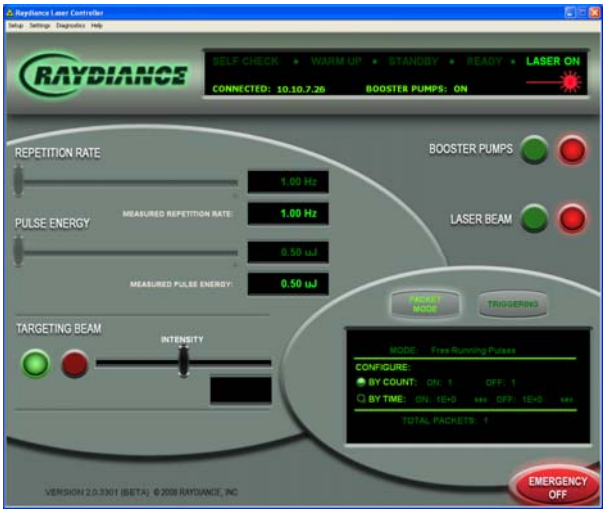

Figure 1: The Raydiance LabVIEW-based user interface. *The user can specify energy per pulse, repetition rate, and various pulse packet modes and triggering parameters*

Once RayOS is booted up, it commands the laser to begin a system self-test, seed system warm-up and calibration, then an amplifier system warm-up and calibration. Internally over 75 controls and sensors are monitored, manipulated, and data-logged by the software control system. Sensors include optical performance monitors, pump current and voltage meters, temperature sensors, mechanical inputs, timing circuits, and external connections for control and safety. Warm up and calibration procedures take approximately 5 minutes, then the system is in "Beam Ready" mode.

System Architecture and Control of Laser Parameters

All of the key components of the Raydiance system are controlled via closed feedback loops. Sensors—the "eyes" of the system—and device controllers are employed throughout the hardware chain to iteratively compare deviations in output signals from set point signals. These feedback loops allow for rapid and accurate stabilization of the system, as well as automatic correction of any errors that might arise from drift or other external sources.

The "front panel" graphical interface allows the user to independently control energy per pulse (from 0.5 µJ to 10 µJ) and repetition rate (single shot to 500 kHz). In addition, the control panel allows the user to set various packet mode and triggering parameters. A packet is simply a set of "on" pulses and a set of "off" pulses, the latter being pulses that are generated but not emitted from the laser. In other words, a user has the ability to specify and deliver a finite number, a free running stream, or arbitrary patterns of pulses.

Application Programming Interface

A core design feature of the Discovery platform is an integrated applications programming interface—software hooks designed into the architecture to allow linking to external software applications. The Raydiance system can be easily integrated into an existing control system, whether an industrial, medical, or scientific application.

Internet-Enabled Remote Access

Owing to its software-centric nature and Internet connectivity, the Raydiance Discovery System has unique capabilities for remote access and diagnostics. Each time the laser is warmed up, and each time the output beam is turned on and off, operational characteristics are recorded by an internal data logging system. With customer permission, these logs can be uploaded via the network connection to a central recording system at Raydiance. Web-based logging and analysis tools provide access to this log data for monitoring, analysis, and fault diagnosis. It is, moreover, possible to use this proactively as a preventative maintenance tool, notifying users of any unusual performance or impending failures if certain control parameters approach their operating limits. The Internet connection also makes remote upgrade and examination possible. New operating parameters or even entirely new software packages can be installed over the Internet, providing bug fixes, improved performance, or even entirely new

features without requiring a service technician's site visit or shipment of the laser back to a support site.

Safety via Cascading Watchdogs

While the primary goal of the software architecture is to provide autonomous and user friendly operation of the laser, a second key advantage is that it provides a redundant safety protocol. The system is designed such that if the laser does not receive constant updates from the user interface it shuts down. Further, without constant update from the embedded software control, the hardware, again, shuts down safely. And the overall failure mode protocol is binary: 100 percent of system components must be functioning properly otherwise the system fails-safe.