Power scaling of excimer lasers drives display and lidar applications

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A new laser concept provides 1.2kW of stabilized UV power for flat-panel display production and high-power lidar stations.

Ultraviolet lasers are critical components of a multitude of systems. In the manufacture of flat-panel displays, they are used to convert amorphous silicon to polysilicon. They are also widely deployed in lidar (light detection and ranging) systems, which compute the distance to a target from the round-trip time of a light ray. Driven by diverse industrial microprocessing markets, the average output power of 308nm excimer lasers has increased along the evolutionary path shown in Figure 1. However, pushing laser systems beyond certain limits adversely affects stability and component lifetime, decreasing yield and raising operating costs. Thus, there continues to be great interest in developing a scalable high-power UV laser design.

Smartphones, tablet PCs, and televisions increasingly rely on high-resolution active matrix liquid crystal displays and organic LED (OLED) displays constructed from polysilicon thin-film transistor backplanes. Conventional amorphous silicon simply cannot meet the requirements of modern flat-panel displays, including longer battery life, faster response time, higher contrast, and finer resolution (see Figure 2). By contrast, polysilicon provides more than a hundred times the electron mobility of the amorphous form.\(^1\) Low-temperature laser annealing is a key step in the process of converting amorphous silicon to polysilicon, and the constant push toward larger substrates demands more powerful beams to reduce production time.

Increasing the power output of excimer lasers also aids in understanding climate changes, both natural and man-made. One typical application of lidar systems is to measure the concentration of high-altitude water vapor, ozone, and other climate-related constituents by vertical sounding: directing a laser beam upward and detecting the radiation backscattered off atmospheric particles. This requires both an extremely powerful laser and a large receiver, given the distance to the climate-relevant upper troposphere and lower stratosphere and the low concentration of trace constituents there.

The schematic in Figure 3 shows the novel dual-oscillator VYPER concept, consisting of two temporally synchronized high-power UV excimer lasers, each capable of a pulse frequency of 600Hz at 1 joule/pulse. Merging the two laser beams achieves an output power of 1.2kW. The beams are mixed and combined externally, at larger beam expansion, to ensure that all optics are operated at only moderate power densities, well below the damage threshold of \(\frac{100\text{W}}{100\text{cm}^2}\). Over a gas lifetime of \(10^8\) laser pulses, the VYPER platform delivers an exceptional output power stability of 0.45% rms, making it suitable for both flat-panel display manufacturing and atmospheric lidar applications.\(^2\)

In the flat-panel manufacturing process shown in Figure 4, beam-shaping optics stretch the annealing beam into a line. This

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Figure 2. Overview of the advantages of polysilicon in flat-panel display devices. a-Si: Amorphous silicon. LCD: Liquid crystal display. OLED: Organic LED. TFT: Thin-film transistor.

Figure 3. The dual-oscillator design of the VYPER 1.2kW excimer laser. HR: High reflector. PO: Power oscillator. PR: Partial reflector.

The line beam is scanned over a thin (typical 50nm) amorphous silicon film on a glass substrate, melting the surface silicon, which then recrystallizes into a homogeneous polysilicon layer.\(^3\) The recent migration in glass substrate sizes from generation 4 (730 x 920mm) to generation 6 (1500 x 1800mm) provides economies of scale, capitalizing on which requires greater line beam lengths and hence a significant laser power upscaling. The VYPER’s twin laser beams can be projected into a homogeneous line beam of dimension 750 x 0.4mm, which quadruples the speed of polysilicon annealing on the larger generation 6 glass substrates.

In atmospheric stations using Raman lidar, the higher average power of VYPER’s 308nm excimer lasers reduces measurement time and improves the signal-to-noise ratio. Within the global Network for the Detection of Atmospheric Composition Change, Earth’s primary greenhouse gas—water vapor, responsible for roughly two-thirds of the planet’s greenhouse effect—constitutes a new focus of lidar vertical sounding, with emphasis on the upper troposphere and lower stratosphere. In contrast to differential-absorption lidar, the Raman lidar method is a zero-background method, and therefore its sensitivity to trace constituents increases directly with increased laser power. Unfortunately, its backscatter signal is three orders of magnitude weaker than that of the Rayleigh method. Most lidar stations today still rely on older excimer laser technology featuring some 10 watts of output power.\(^4\) Figure 5 shows an extension of Raman lidar sounding of water vapor into the stratosphere, currently being conducted at the Schneefernerhaus high-altitude station, next to Germany’s Zugspitze summit. The new system uses a multi-hundred-watt 308nm excimer laser system and a large 1.5m-diameter receiving telescope, giving a higher achievable altitude and smaller error bars. With a reported backscatter signal increase of two orders of magnitude over existing lidar systems, the installation is expected to provide temperature profiles up to an altitude of 80km.\(^5\)

Figure 4. The excimer laser annealing principle (left) and the resulting polysilicon layer (right). p-Si: Polycrystalline silicon.

Figure 5. The NDACC (Network for the Detection of Atmospheric Composition Change) high-altitude lidar station at the Zugspitze summit, Germany.

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Our ongoing research aims to extend the modular VYPER dual-oscillator system by taking advantage of further upscaling in the power of modern excimer lasers. Increasing the system’s total output energy will permit more accurate and more extensive lidar monitoring of Earth’s atmosphere. In the polysilicon backplane industry, it will both increase throughput and support the very long annealing lines required by the newest (generation 8 and 10) panels, which are used in the largest-format low-temperature polysilicon-based OLED displays.

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References