Excimer light sources for photolithography must not only generate spectrally narrow output but also produce output pulses with precisely controlled energy. Conventional excimer lasers, based on a single-chamber design, produce narrowband output by using optical filters to select only a small portion of the full spectrum generated by the system, discarding the out-of-band energy. Because this line-narrowing process significantly reduces pulse energy, a single-chamber light source already operating at maximum pulse energy must increase repetition rate in order to meet output power requirements. High repetition rates place excessive demands on the chamber design, so designers are forced to make a tradeoff between optimizing either spectral bandwidth or pulse energy, since operational margins are insufficient for both.

This tradeoff limits the ability of single-chamber designs to meet performance requirements for future photolithography applications. A master oscillator power amplifier (MOPA) dual-gas-discharge-chamber architecture offers one method for overcoming these limitations.

In the MOPA configuration, the functions of spectral bandwidth and pulse energy generation are separated between two chambers, with each chamber optimized for one performance parameter. This configuration allows the simultaneous improvement of both spectral bandwidth performance and increased output power without increasing repetition rate.

The first discharge chamber, the master oscillator (MO), is designed to produce output with a very narrow spectrum (typically no more than 0.25 pm FWHM for argon fluoride and krypton fluoride models) at pulse energies on the order of 1 mJ when excited by compressed, short-duration, high-voltage electrical pulses. The MO chamber is situated within a resonator structure consisting of an output coupler and a high-dispersion line-narrowing module (LNM).

Although a significant amount of energy is lost through the line-narrowing process, a high-dispersion LNM can be used since the MO output will be subsequently amplified by the PA to the required pulse energy level. Single-chamber-based lithography light sources cannot use high-dispersion-ratio LNMs and meet necessary pulse energy levels. The separation of performance parameters by the MOPA configuration overcomes this fundamental limitation.

The second chamber is the power amplifier (PA). The PA discharge amplifies the line-narrowed, low-energy output pulses from the MO to meet output power requirements (typically 40 to 80 W) with no change to the spectral properties of the light. Synchronization between the independent MO and PA chamber discharges is essential to the amplification process to ensure that spectral bandwidth properties are maintained.

A subsequent pulse stretcher splits off a portion of the output, sending it through multiple delay lines and relaying the imaging, or the delayed portion(s), back onto the “parent” beam. The incorporation of an optical pulse stretcher is necessary due to the possibility of index of refraction changes that fused silica may undergo after long-term exposure to UV radiation.

An optical subsystem relays the beam from the MO through the PA to the input of the pulse stretcher. The relay optics subsystem consists of the MO wavefront engineering box (WEB), which directs the MO output towards the PA WEB, which directs the beam into the PA chamber. A subsequent beam reverser module directs the amplified beam back through the PA gain medium in a final power gain pass. To ensure that the returning amplified beam does not interfere with the injecting optic in the PA WEB, the beam reverser returns the beam on a slight tilt, which spatially separates it from the injecting optic. We also divert a low-power sample of the radiation to obtain in-situ metrology.

The dual-chamber MOPA design offers enhanced spectral power capabilities, providing an economical, high-performance alternative to current systems.

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