Generation of highly coherent, bright 13 nm light with phase-matched high-order harmonics for coherent scatterometry microscope

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Mask yield and defect inspection are recognized as the most important critical issues for high volume manufacturing EUVL. At-wavelength mask inspection will be required to detect phase defects inside a multilayer. We have developed a coherent scatterometry EUV microscope (CSM) in NewSUBARU to solve this issue. [1] But because of low fluence of the coherent component of the synchrotron radiation, the throughput of inspection process is not enough. High-order harmonics (HHs) is an attractive light source to increase the fluence of spatial coherent light on a EUVL mask. [2] Energy conversion efficiencies as high as 10^{-7} for each HHs have been achieved at wavelength around 13 nm using sub-TW pump laser pulses under phase-matched conditions. [3] The purpose of this study is generation of highly spatial-coherent, bright 13.5 nm (59th) HHs using a commercial, table-top, sub-TW, femtosecond Ti:sapphire laser system.

Schematic diagram of experimental setup for HHs generation system is depicted in Figure 1. We focused 32 fs, 6mJ laser pulses from a 1 kHz laser system (Spitfire Pro 6W) into a semi-infinite gas cell filled with He and Ne gas to achieve a fluence of 1 nW, which is about 1000 times higher than the current fluence, on the mask. The f/125 focusing achieved a peak intensity of 1×10^{15} W/cm^2 in vacuum. Typical HHs spectra seen in Fig.2 were observed in 9-, 13.5-, 18 kPa He gas. We observed an enhancement of 13.5 nm HHs, by a factor up to 100, when the helium gas density was doubled. This result is positive evidence that phase matching conditions are satisfied at the optimized gas density. [4] Measured beam divergence of the 13.5 nm HHs were 0.21 and 0.17 mrad at optimized gas density for He and Ne, respectively. To our knowledge these are the lowest beam divergence ever measured for any HHs beam. These results suggest that the 13.5-nm HHs generated with commercial laser system has fully spatial coherence equivalent to the pump laser pulse.

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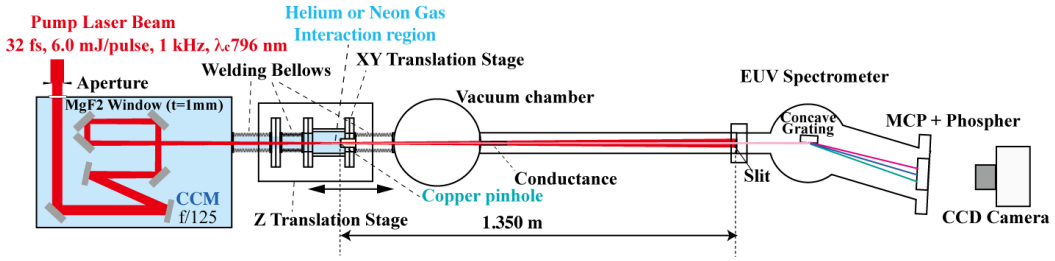

Figure 1 Schematic diagraph of high-order harmonics generation system using semi-infinite gas cell.

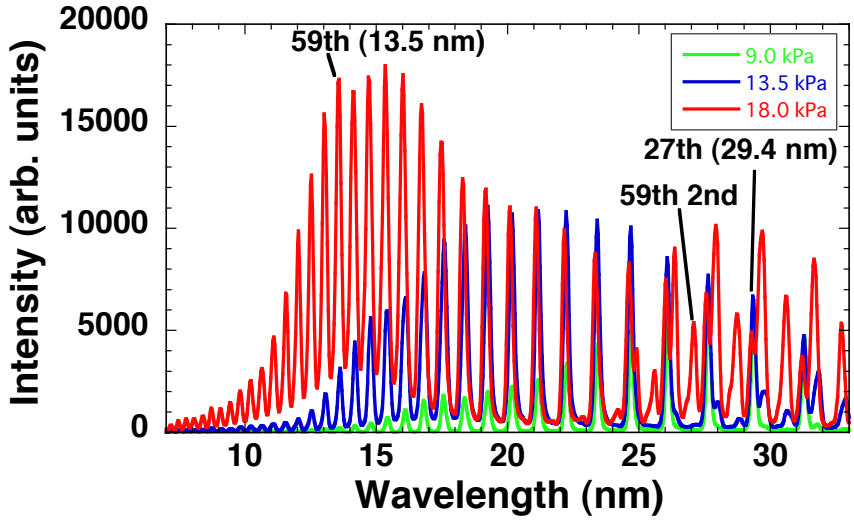

Figure 2 Pressure dependence of high-order harmonics spectra in He gas.