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Protected Mirrors Enabling Storage Ring FEL Lasing below 170 nm

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In a storage ring free-electron laser (FEL) the cavity mirrors have to resist the harsh operational conditions due to high-energetic and background radiation in an ultra-high vacuum environment. For the wavelength between 120 and 190 nm only fluoride materials are suitable as coating material for high reflective mirrors. However, used in the bare form, they are not stable for extreme FEL operation conditions. Until this work, it was not possible to achieve the lasing below 176 nm with an oscillator FEL. The collaboration between DUKE University/TUNL and Laser Zentrum Hannover e.V. has recently demonstrated the storage-ring FEL lasing between 169.6 and 176.7 nm. For this work, different coating techniques such as ion beam sputtering, thermal evaporation, and atomic layer deposition were employed to produce samples of a single-layer, multilayers, and a version with a protection layer. All samples were irradiated using Duke FEL undulators and characterized with VUV spectrometry from 140 to 230 nm. We have found that the SiO_2-protected fluoride coatings have good thermal stability and radiation resistance. Several sets of mirrors have been coated and used to demonstrate the FEL lasing in a new VUV range with a reasonable lifetime. These mirrors have also been used to generate 120 MeV gamma rays via Compton scattering. The newly developed coating strategies are expected to enable the storage-ring FEL to operate in even shorter wavelengths.

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