Thin film X-ray waveguides: "condenser systems" for submicron resolution x-ray microscopy

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In the hard x-ray range one finds that the refractive index of any material is slightly smaller than unity and that it increases towards lighter elements (low-Z). The consequences for an x-ray beam incident in vacuum (or air) are: a) the lighter the element the smaller is the grazing cutoff angle for total reflection b) a penetrating incident beam is refracted towards the interface . If the reflectivity of a thin low-Z-film on a high-Z-substrate will show a deep minimum below the critical angle of the substrate the incident energy is trapped in the low-Z-film with a significant intensity increase. For this reason this phenomenon is called "resonant beam coupling". Then the electromagnetic modes, which have their nodes at the interfaces, are exited and travel in the film parallel to the surface (waveguide condition). In waveguides optimized for photon energies from 13 to 30 keV where the low-Z-film is amorphous C the beam intensity increases to more than 100 times the incident intensity. This is achieved for film thickness around 0.1 micron, and thus the x-ray beam exiting at the waveguide end is very promising for micro-spot techniques. The phase space acceptance of these objects is very small (< 0.1 nm rad); it turns out to be almost identical to the maximum phase space volume of a coherent source (divergence x size = wavelength). For this reason a high exit flux can only be obtained at the new third generation high brightness x-ray sources (like e.g. ESRF, APS, SPRING8, ALS, ELETTRA). While the first exiting beams were observed by us [1] and others [2] at undulator beamlines at the ESRF, the system efficiency could recently be improved by orders of magnitude [3], such that their application at even less powerful radiation sources for the x-ray range becomes feasible. The properties of the exiting beam such as its size and its coherence will be presented. The recent successful application of such a waveguide in the first phase contrast projection microscope with submicron resolution will be discussed in more detail. At an undulator source exposure times of fractions of a second were possible, so that even dynamical studies could be performed. Experiments at different ESRF bending magnet stations were performed, requiring, however, longer integration times, limiting the studies to static systems.

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