Application Note: Focusing X-rays With Zone Plates For Synchrotron Use

Xradia's x-ray zone plates are commonly used for high-resolution focusing of x-rays in synchrotron applications. The resolution (or probe size) is limited to the Rayleigh resolution 1.22 δr, where δr is the outermost zone width of the zone plate.
To achieve the Rayleigh resolution (also called diffraction limited resolution), the x-rays illuminating the zone plate have to be spatially and temporally coherent, which means that they have to be both sufficiently collimated and monochromatic. The criteria are as follows:

Spatial coherence / source demagnification

Zone plates act as thin lenses. They therefore can be used to create a demagnified image of the x-ray source (e.g. virtual source being the exit slit of the monochromator). The image size can be calculated using the imaging equation $1/f = 1/i + 1/o$, where i and o are the image and object distances respectively. The demagnification is given by $M=i/o$.
To reach the diffraction limited source size, the combination of source size and source distance o must result in an image size equal or smaller than the diffraction limited size calculated by the formula 1.22 δr.
If the source is too large (or the demagnification too small due to small distance to source), the actual focal spot size can be computed using the formula for demagnification given above.

Temporal coherence / monochromaticity

Since zone plates are diffractive optics (circular gratings), different wavelengths are focused at different focal lengths according to the formula $f=2r\,\delta r / \lambda$, where r is the radius of the zone plate, δr the outermost zone width and λ is the wavelength. To achieve a focal spot not limited by the wavelength spread of the x-rays, the monochromaticity $\lambda/\Delta\lambda$ should be greater than the total number of zones of the zone plate, which is given by $r/(2\,\delta r)$.

In summary, the x-ray source size, distance between the source and the zone plate and the monochromaticity of the x-ray beam need to be considered to achieve diffraction limited resolution.

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