# Electron density modulation via electron diffraction

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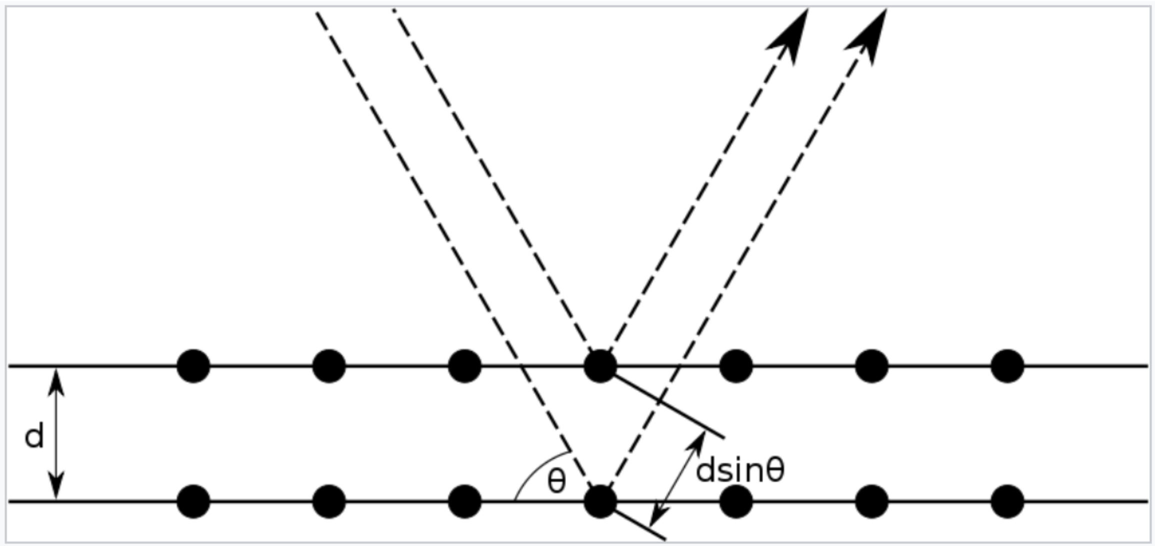
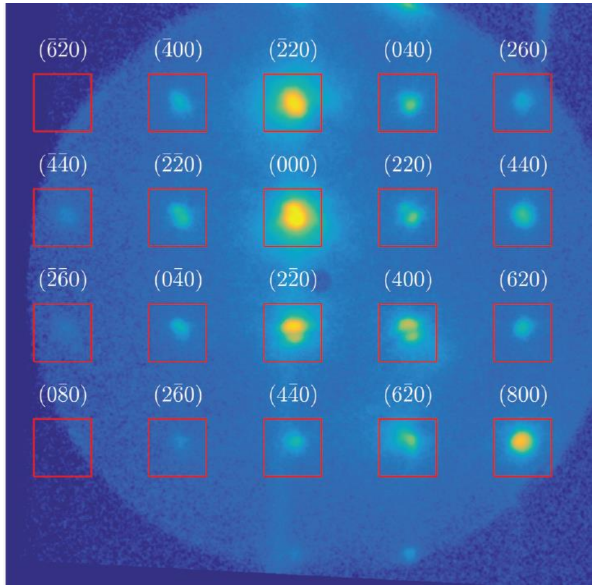
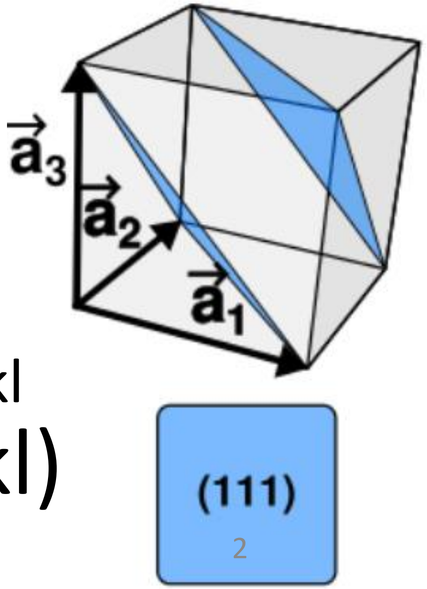
# Electron diffraction

Bragg's law: $n\lambda = 2d_{hkl}\sin\theta$



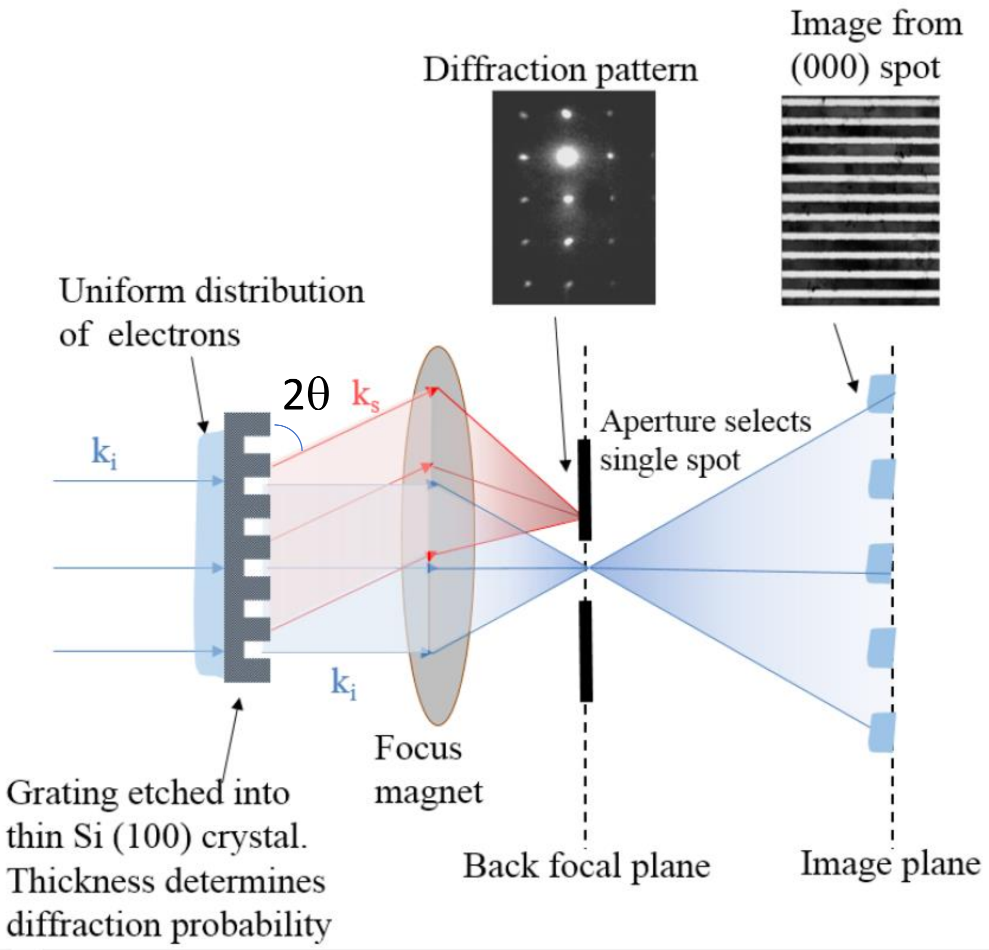

*Malin et al. THPAB088, IPAC2017*




Lattice planes have different orientation (hkl), and $d_{hkl}$

Can orient crystal to maximize specific Bragg peak (hkl)

# Producing transverse electron density modulation




*Graves et al.*
*Arxiv:1906.01525 (2019)*

Diffraction only at thick grating sections ->
Non-diffracted electrons have the same transverse pattern as grating.

Select the non-diffracted beam with an aperture and make an image.

Need sufficiently large deviation angle, $2\theta$, of the diffracted beam compared with the e-beam angular spread, $\sigma'$, in order to block it.

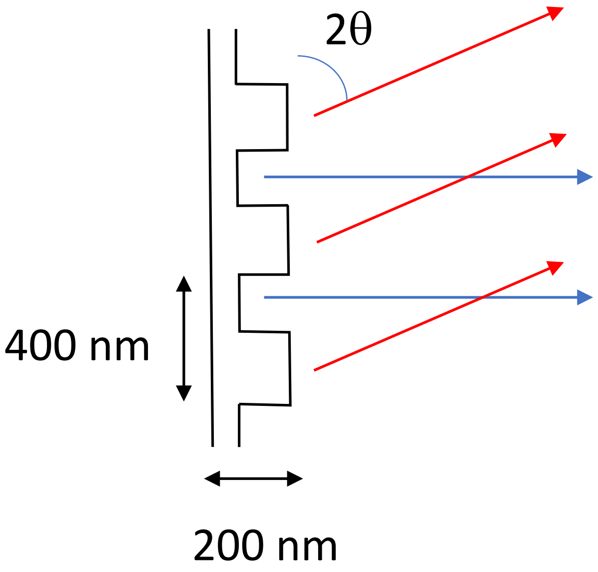
**Required electron-beam emittance:**

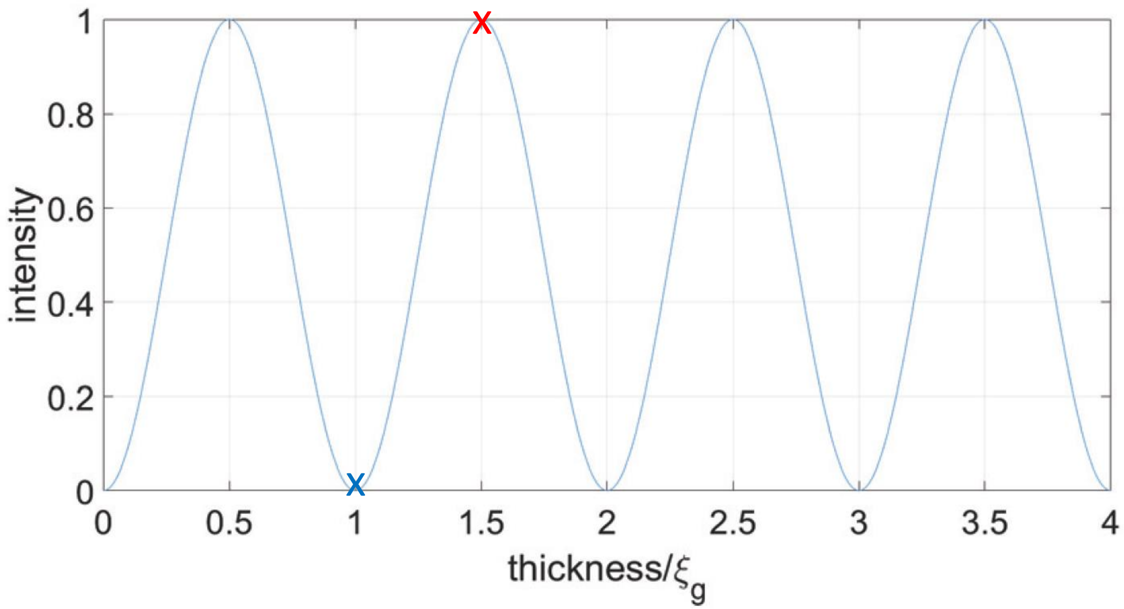
Assume $\sigma' < 0.1 \times 2\theta$

$2\theta = 1.1$ mrad for the (111) Bragg peak in a Si crystal for E=3 MeV.

-> required emittance $\varepsilon = \sigma\times\sigma' = 300^{-6}\times(0.1\times 2\theta) =$ 34 nm rad
for a beam of $\sigma = 300$ $\mu$m width.

# Optimizing the density modulation




*Diffracted intensity as function of crystal thickness (for $\varepsilon$=0)*

$$I = sin^2(\frac{\pi z}{\xi_g})$$

$\xi_g$ is the crystal extinction length ~100 nm

*Zhang et al. MOPAB150, IPAC2017*

- Choose grating thickness that maximizes the number of diffracted electrons in thick sections and minimizes in thin sections
- Align crystal to satisfy Bragg's law
- Thin crystals (~100 nm) to avoid e.g. multiple scattering and inelastic scattering
- Small emittance of electron beam desired

95% diffracted electrons demonstrated for 200 nm thick Si crystal

*Graves et al. Arxiv:1906.01525 (2019)*