Measurement of spherical aberration coefficient in Scanning Transmission Electron Microscopy (STEM) from image displacement

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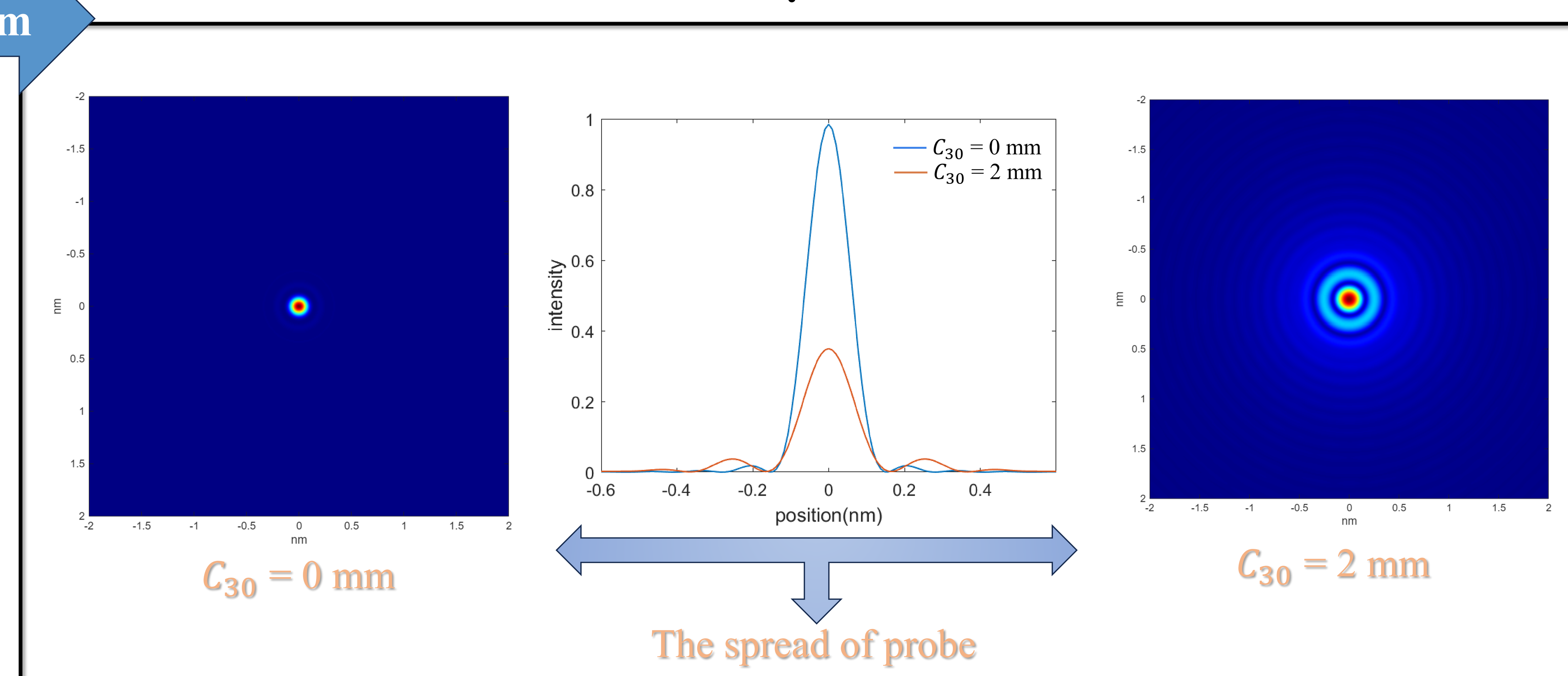
Abstract

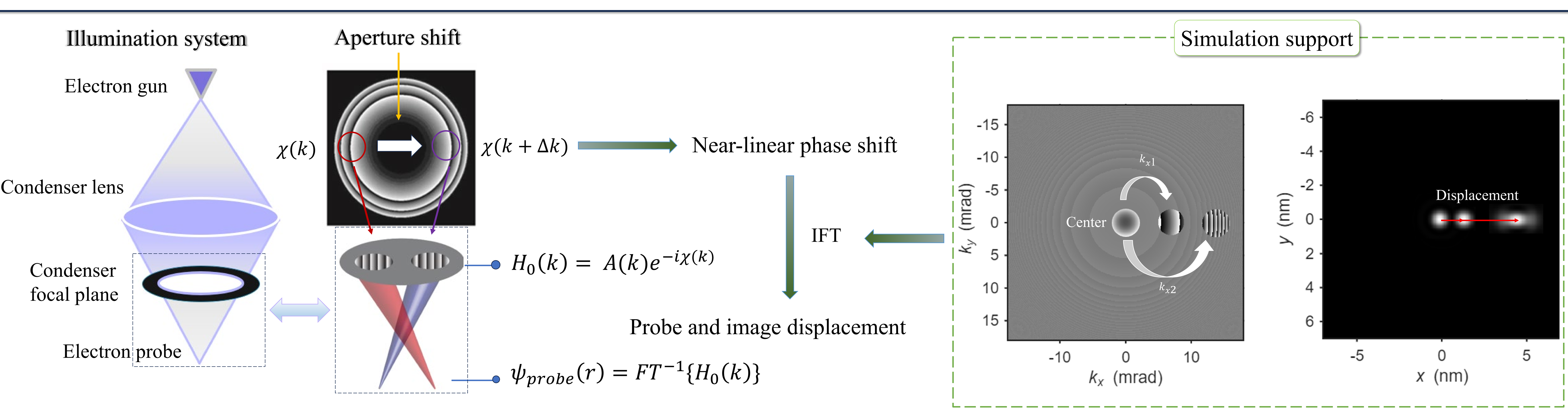
Transmission electron microscope(TEM) has achieved sub-Å spatial resolution owing to the breakthrough of spherical aberration correction technology. Accurate determination of spherical aberration coefficient (C_{30}) is a necessary condition for correction of spherical aberration corrector. An improved method proposed here is to traverse the focal plane while varying the position of a small condenser aperture. The probe and corresponding scanning image have relative displacement due to the almost linear phase shift within the aperture. The local phase gradient is reconstructed by the image displacements, and the C_{30} on the focal plane of the lens is successfully recovered.

Problem

The influence of spherical aberration



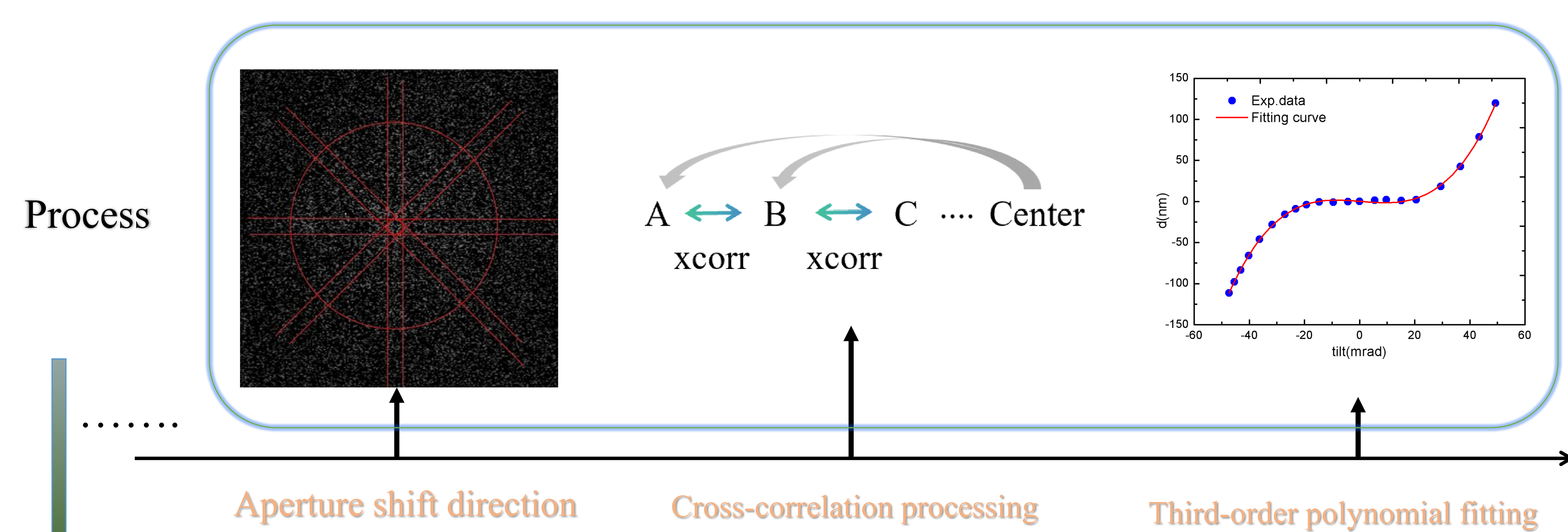
Method



Results

Accurate measurement of single aberration——c_{30}

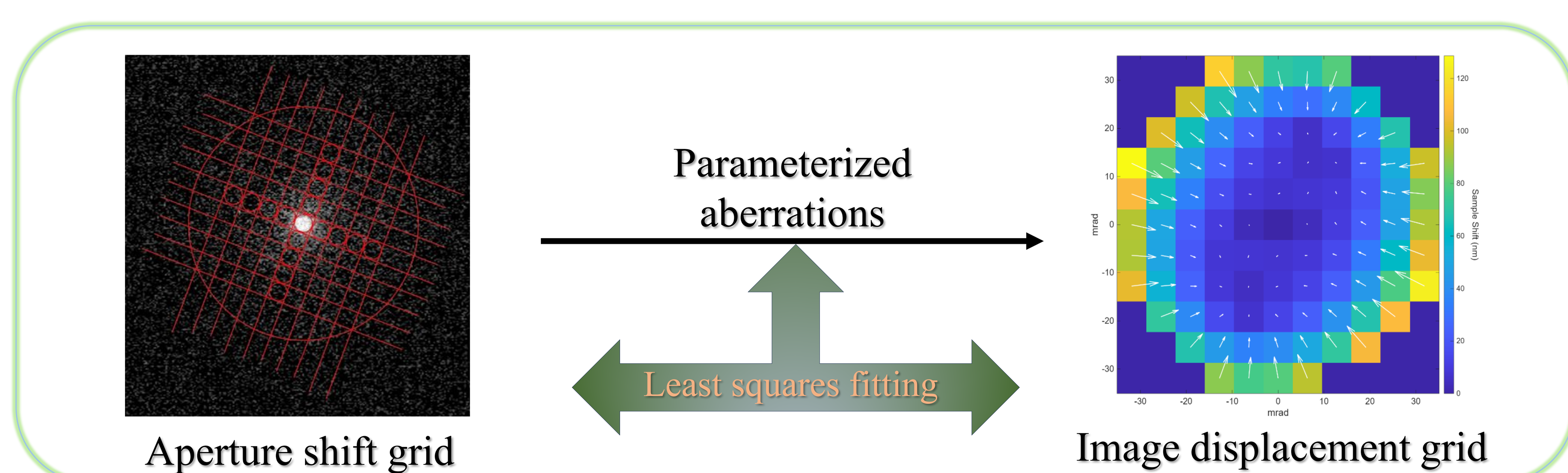
1D aperture shift



Fitted spherical aberration

Emission voltage (kV)	C_{30} (mm)	Variance (mm^2)	Standard deviation (mm)
200	1.11	0.002	0.044
80	3.05	0.006	0.077

2D aperture shift



Aperture shift grid

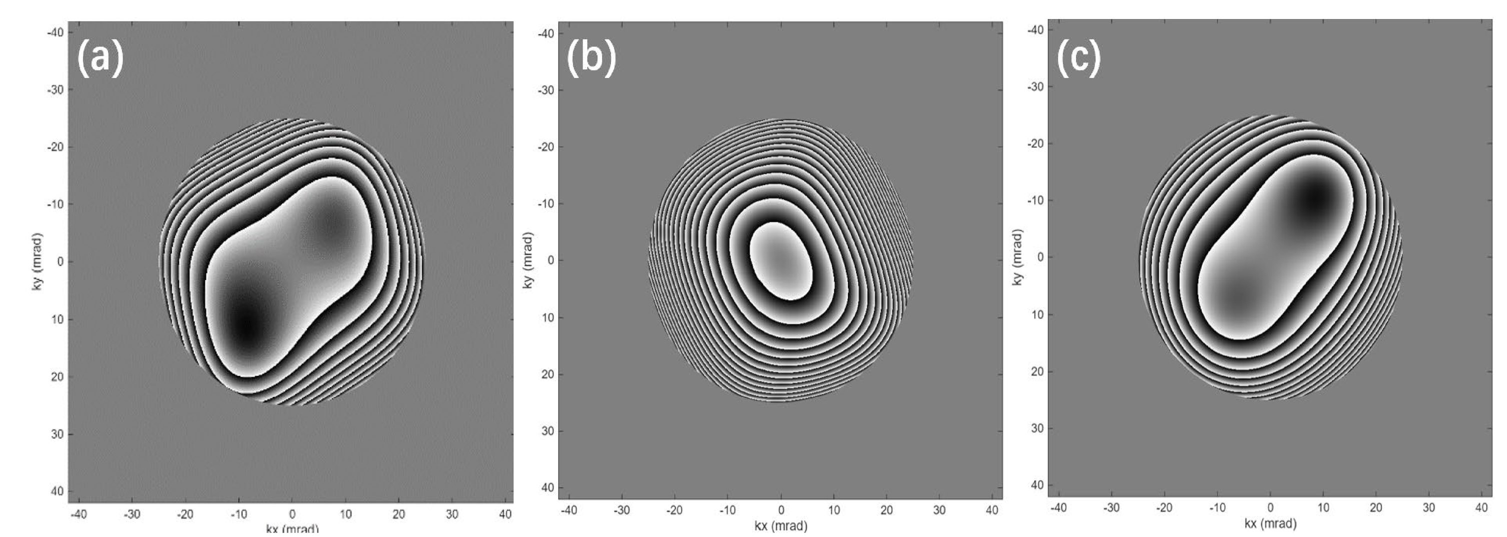
Image displacement grid

Successful measurement of full aberrations

Parameterized full aberration

$$\chi(k,\phi) = 2\pi \sum_{mn} \frac{1}{n+1} C_{nm} \lambda^n k^{n+1} \cos[m(\phi - \phi_{nm})]$$

Reconstructed phase plate



Fitted full aberrations

Aberration coefficients	Group (a)	Group (b)	Group (c)
C_{10} (nm)	-18.63	422.18	23.66
C_{12a} (nm)	-30.80	76.51	20.85
C_{12b} (nm)	124.25	-141.69	155.25
C_{21a} (μm)	0.92	-0.74	1.99
C_{21b} (μm)	-4.65	-2.62	5.20
C_{23a} (μm)	0.35	0.84	0.74
C_{23b} (μm)	0.76	-2.23	1.99
C_{30} (mm)	1.05	1.03	1.08
C_{32a} (μm)	41.42	40.95	30.35
C_{32b} (μm)	6.87	17.60	-0.94
C_{34a} (μm)	-0.08	5.72	10.49
C_{34b} (μm)	-229.58	-332.35	-37.32