Camera terminologies and diffraction blur

1. What is an f-number?
   N = f/D
   where f is the focal length of the lens, D is effective aperture.

   Modern cameras use f-numbers as powers of sqrt(2).
   Camera aperture D = *f*/1, *f*/1.4, *f*/2, *f*/2.8, *f*/4, *f*/5.6, *f*/8, *f*/11, *f*/16, *f*/22, *f*/32 …

2. What does aperture affect?
   i. Large aperture - shallow depth of field (less physical depth is “in-focus”). High light exposure.
   ii. Small aperture - large depth of field (everything is in focus). Less exposure, due to small entrance for light.

3. What is used for long/short distance imaging?
   For a fixed focal length :
   Large aperture/large angular extent - N = 1,1.4,2,2.8 -- close-ups/shallow depth of field, focused object is at the center of this field.
   Medium aperture - N = 11,16 -- mid-range
   Small aperture/small angular extent - N = 22,32 -- long-distance imaging/large depth of field

4. What is the effect of focal length of lens?
   Short focal lengths correspond to wider angle view of scene/zoomed out.
   Large focal lengths correspond to narrower view/zoomed in.

5. What is diffraction blur?
   http://www.cambridgeincolour.com/tutorials/diffraction-photography.htm
   https://photographylife.com/what-is-diffraction-in-photography
   Notes:
   i. Essentially depends on angular extent of input aperture.
   ii. Diffraction spot size = (wavelength of light)*(distance of object from lens)/(aperture diameter)
   iii. High diffraction blur when (1) aperture is small (2) images are at a large distance
   iv. Airy discs are formed. If dia of airy disc is larger than single pixel of camera, one tends to observe effects of diffraction blur.
   v. Becomes harder to resolve edges as the airy discs of distinct points overlap considerably (can be resolved only if Rayleigh criterion is met).
   vi. Occurs due to phase-difference of light diffracted from two extremes of aperture.

6. Aperture D depends on N and f, one can reduce effects of diffraction blur by using large lens (fixed focal length f, larger D, smaller N).

7. Long-distance imaging - higher diffraction blur can be reduced by using larger lens (however this can be as big as f = 125mm, expensive).

Super-resolution

Low resolution causes:
(intrinsic - related to camera setup, extrinsic - related to type of data/scene):

1. Less number of sensors in the camera hardware/pixel subsampling (finite pixel size) (intrinsic).
2. Diffraction blurring (intrinsic).
3. Lens aberrations (intrinsic).
4. Shot noise, sensor noise (extrinsic, intrinsic)
5. Motion (extrinsic)
6. Air temperature, wind shear (extrinsic)

Features of the paper:

Toward Long Distance, Sub-diffraction Imaging Using Coherent Camera Arrays

1. Aims to solve the small aperture problem by generating larger aperture synthetically, using a camera array (a setup commonly used in fourier ptychography, but not in long-distance imaging).
2. The imaging process is done using a transmissive mode (light source is placed behind a *thin lens-like object* embossed with opaque design that needs to be imaged) [this is different from the usual reflective mode imaging, but one can draw parallels].
3. The *thin glass object* induces a phase shift in the transmitted rays - this is what converts the spatial-domain image into its Fourier equivalent (Fraunhofer approximation). *Thus, the thin-object approximation is crucial to this problem setup*.
4. For an N x N grid of cameras, the synthetic aperture is approximately N times the original aperture, hence improving diffraction blur by factor N.
5. The phase problem: this problem usually arises in Fourier imaging systems: The light waves to be captured are complex in nature, but detectors can only estimate magnitude (measurements are in terms of photon or electron counts).
6. Point to ponder over:
   + Capturing image in Fourier domain seems to circumvent effects of diffraction (would be good to find an optics reference for this).
   - However problem with Fourier imaging is loss in phase - hence requiring phase retrieval strategy to construct inverse Fourier transform.