The formula for computing PSF of high NA objective is that

$$\mathbf{E}(r_P,\theta_P,\varphi_P) = -\frac{ik}{2\pi}\iint \cos^{\frac{1}{2}}\theta\cdot\mathbf{P}(\theta,\varphi)\cdot\sin\theta e^{ikr_P(\cos\theta\cos\theta_P+\sin\theta\sin\theta_P\cos(\varphi-\varphi_P))}\,d\theta d\varphi, \text{ --------- } (1)$$

Where: $\mathbf{P}(\theta,\varphi)$ is conversion matrix for polarization state from initial state (incident light polarization) to focal region.

$$\mathbf{P}(\theta,\varphi) = R^{-1}CR\mathbf{P}_0 = \begin{bmatrix}\vec{p}_x\\ \vec{p}_y\\ \vec{p}_z\end{bmatrix}\begin{bmatrix}1+(\cos\theta-1)\cos^2\varphi & (\cos\theta-1)\cos\varphi\sin\varphi & -\sin\theta\cos\varphi\\ (\cos\theta-1)\cos\varphi\sin\varphi & 1+(\cos\theta-1)\sin^2\varphi & -\sin\theta\sin\varphi\\ \sin\theta\cos\varphi & -\sin\theta\sin\varphi & \cos\theta\end{bmatrix} \text{ ----(2)}$$

There is one paper from Lars Egil Helseth: "Focusing of atoms with strongly confined light potentials" explained it in detail.

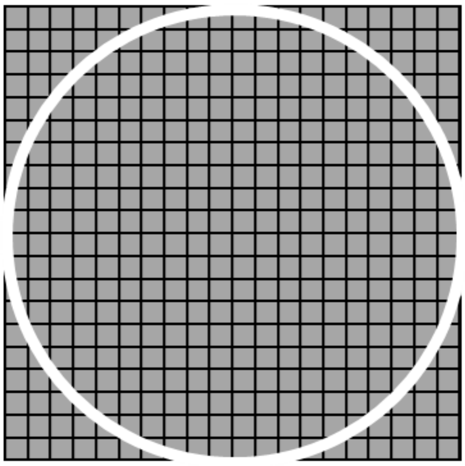
Yes, I've tried the idea which you proposed in your post before.

<<I now rather think that you have to average over waves entering under slightly different angles or from different points (depending on the characteristics of the incoherent light source!>>

## Coherent (normal case)

**The figure illustrates the diffraction grid on the exit pupil of aperture.**

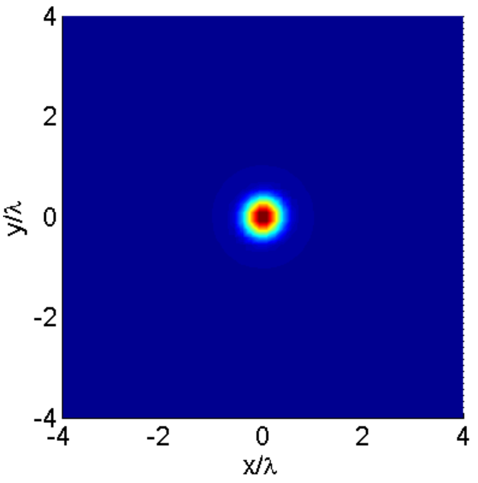
**The white circle is the lens aperture, the ray outside of this circle has no contribution to forming of PSF in the focal region.**



In the case of coherent, all the light is mature coherent, so

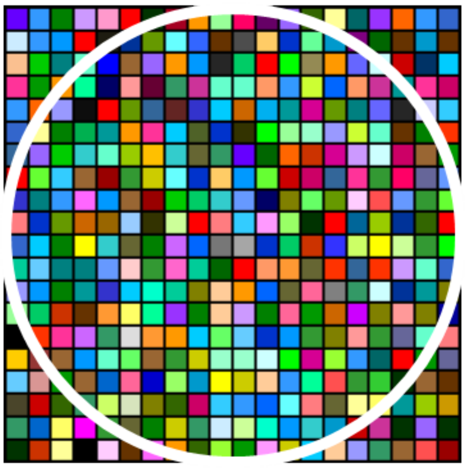
$$E_{totoal} = E_{\theta=0}\ldots\ldots + E_{\theta=i}\ldots\ldots + E_{\theta=\alpha},$$
$$0 \le i \le \alpha$$
$$I_{total} = EE^*.$$

Shape of focusing spot in focal region. Xy plane.




## Incoherent

**The figure bellow is illustrate the diffraction grid on the exit pupil of aperture, the random color indicate the random phase.**

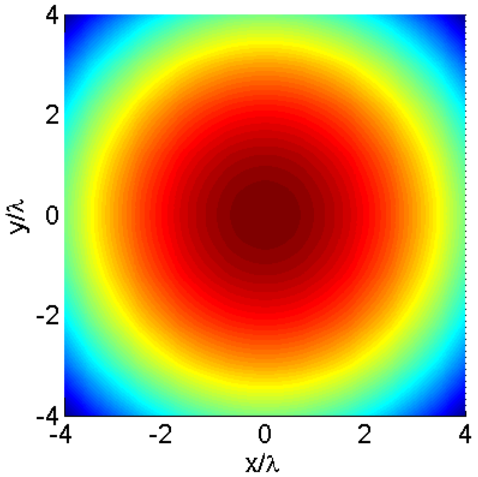


**But** In the case of incoherent, there is no interaction between each ray, so

$$I_{\theta=i} = E_i E_i^*$$
$$I_{totoal} = I_{\theta=0} \ldots\ldots + I_{\theta=i} \ldots\ldots + I_{\theta=\alpha},$$
$$0 \le i \le \alpha$$

But the result is really depends on how small angle you choose and how much rays for each small angle.

Here the small angle is $\alpha/200$. For each small angle there are ten rays. If I choose only one ray, for instance, $\theta= \alpha/2$, $\varphi=2\pi/2$, the electromagnetic field in focal is planar wave. And the corresponding intensity I=(E)^2, is constant everywhere.




If I choose small angle and less rays for each, the PSF is even bigger and bigger.

Is it same case which you proposed in your post? (if I understood correctly )

Perhaps, maybe the diffraction formula is no longer suitable in the incoherent case.