Thomson Scattering Signal and Uncertainty

The Alcator C-Mod incoherent Thomson scattering system has the following parameters.

Laser pulse energy	1	J
Wavelength	1.064	μm
Duration	8	ns
Scattering Angle	90	deg
Laser Beam Diameter	3	mm
Scattering Length	6	mm
Collection optics aperture diameter	0.14	m
Optics distance from scattering vol	1	m
Optical Transmission Efficiency	50	%
Detector Quantum Efficiency	20	%

Using non-relativistic Thomson scattering approximations, estimate the following characteristics when scattering from a plasma of the following approximate (uniform) parameters: $n_e = 2. \times 10^{20}$ m^{-3}, $T_e = 2$ keV, $Z_{\text{eff}} = 1$, diameter along viewing chord 0.4 m.

(a) The value of $k\lambda_D$ (to check we are really in the incoherent regime).

(b) The total number of scattered photons detected over the entire scattered spectrum (for a single laser pulse).

(c) The fractional uncertainty in the measurement of plasma density resulting purely from scattered-photon statistics. [Hint: consult Appendix 2.]

(d) The spectral width of the scattered signal out to a frequency (or wavelength) displacement where the signal has fallen to e^{-2} of its peak intensity.

(e) The total number of plasma-light photons detected in this spectral width, during a time period of 8ns (the pulse duration), assuming that all the photons arise from bremsstrahlung.

(f) The number of plasma-light photons if the time period is 160 ns (to accommodate detector speed limitations) and the plasma emission is 10 times higher than bremsstrahlung (because of impurity radiation).

(g) The photon-statistical density-measurement fractional-uncertainty including plasma-light photons of case (f).

Since the non-relativistic spectral distribution has a Gaussian shape, one can use well-established statistical theorems to show that the standard-deviation in the measurement of its width from a sample of N photons is equal to the standard-deviation of the distribution times $1/\sqrt{2(N-1)}$ (in the absence of noise photons). It is approximately a factor of $\sqrt{1+4N_b/N}$ larger in the presence of a uniform background of N_b noise photons.

(h) What is the approximate fractional uncertainty in T_e measurement arising from photon statistics?