X-ray speckle contrast calculation

In the paper, the formula reads like this:

Here, the   is wavevector of scattered photons. The photon momentum transfer  .

For hard x-ray pulse, the sample thickness is usually much less than the Rayleigh length. Assume the . Then we have the following relation within the integrated space time regime,

We follow the same convention as that in REF [1] and use the time axis to describe both the time and z axis during evolution. Define . Assume that (0,0,0) is the intersection point between the z axis and the sample.

In this case, the is the envelope of the electric field as defined in equation (2.1) in REF [1].

Therefore

## Derive the physical quantity we directly measure.

If we ignore the photon shot noise due to quantum fluctuations, the detector pixel reads the scattered electric field energy over the whole pulse.

Assume that the detector pixel is (a square) is infinitely small and is perpendicular to the scattering direction  . Then, the measured correlation is.

Also, consider the actual condition. We are calculating the average over many pixels.

The reason for including both pattern average and pixel average is explained later in **bold font**.

Here, the integration over the time , is the integration over the infinite time. The delay time is achieved with the definition of and .

Here, the and refers to the first and second x-ray pulse in the x-ray pulse pair in this dataset.

Here, we assume that the pulse duration of each pulse is far smaller than the pulse separation .

In this case

Assume that the correlation length of the sample is much smaller than that of the x-ray pulse in all dimensions. Then only two situations contribute to the results significantly. and .

Furthermore, assume that the pixel average and pulse average makes the evaluation of the part and the part independent. This is the reason why we need to include the pixel average in this calculation.

**In practice, we sometimes measure the speckle contrast from each pulse with a static sample and consider this as the contrast of the x-ray pulse. In this case, the meaning of the first equation of this note becomes vague. Since we only have a single x-ray pulse and a single sample configuration** . **The decomposition** **used below is no longer meaningful.**

**By including the pixel average, we resolve this issue. We consider different speckles across different pixels effectively realize the ensemble average over independent sample configurations. Then, this effective ensemble average makes the independent evaluation of the two factors valid.**

For the first case:

The is the sample thickness. The and are the pulse energy. (I think there is an error about this statement. However, it should not change the derivation.)

Now consider the case 2

Here, we have assumed that the temporal support of and is separated by a delay time and within the pulse duration, the sample does not change at all.

Now, assume that the separation of the two pulses is far larger than the pulse duration, and assume that the two pulses have exactly the same envelope

In this way, I am now very happy with the result and believe that our calculation is valid.

## Note1

For different pixel and therefore different R and K, its influence on the

Is small since we assume the electric field change slowly.

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| Reference |
| [1] Pusey P N. Statistical properties of scattered radiation[J]. Photon correlation spectroscopy and velocimetry, 1977: 45-141. |
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