Possibility of realizing Bussey's thought experiment on collapse of the wave function at the microscopic level

Kouichi Toyoshima, Takasi Endo and Yutaka Hirayoshi
University of Saga, Japan

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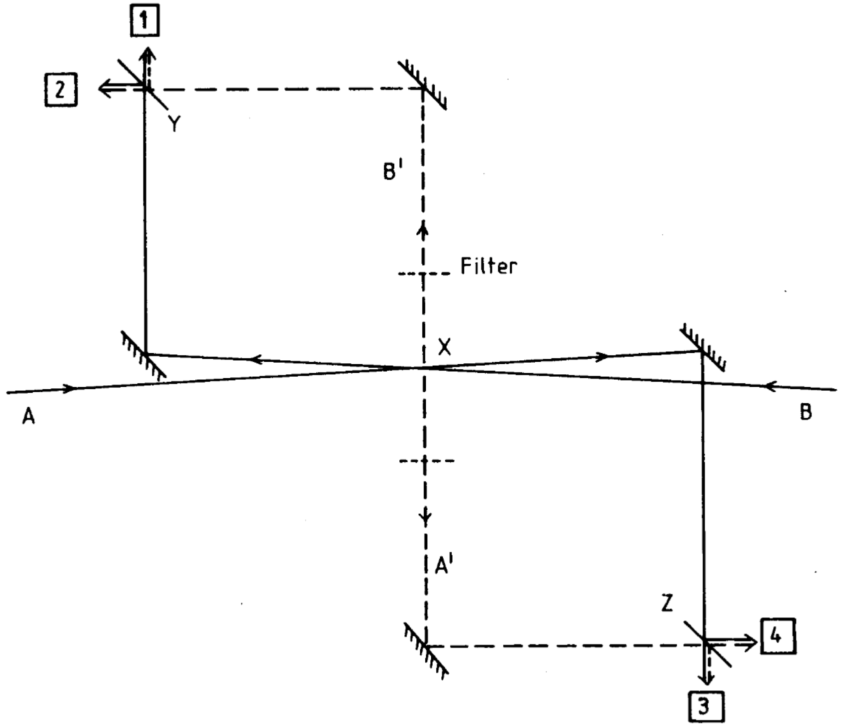
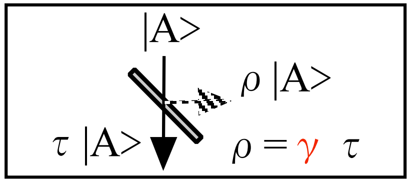


Fig. 1. The double interferometer. The filters remove scattered particles of type A′ from the B′ arm, and vice versa.

[1] P.J. Bussey, Phys. Lett. 106A(1984) 407

Parameters τ, ρ, γ
of the beam splitter
(symbols 'Y' and 'Z' in figs.)



if $|\Psi> = \alpha\,|A>|B> + \beta\,|A'>|B'>$ (non-collapse)

$C_{13} = |\tau|^4\,|\alpha - \beta|^2$, $C_{14} = |\tau|^4\,|\alpha + \beta|^2$ for $\gamma = e^{i\pi/2}$

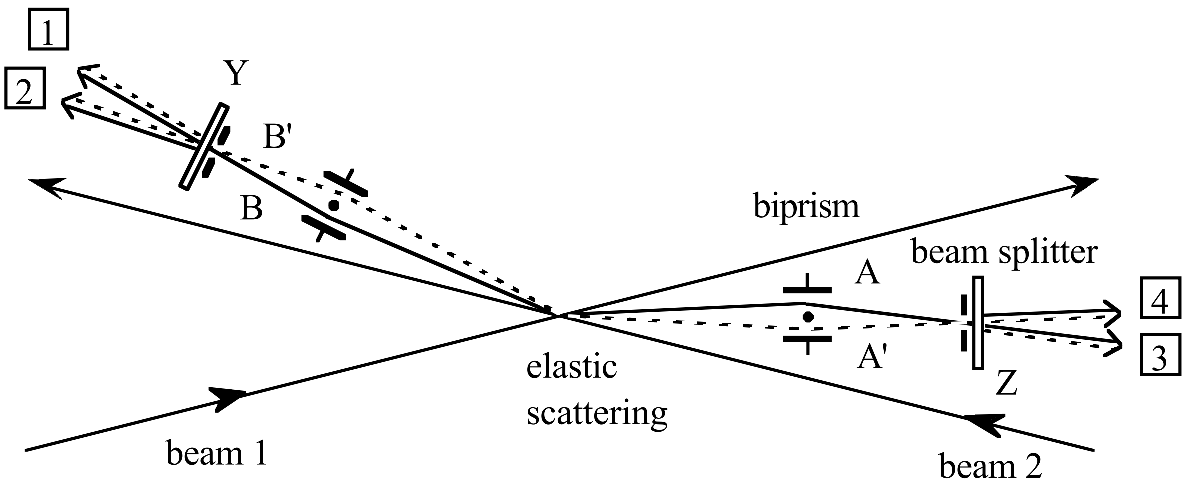
[for general γ : $C_{13} = |\tau|^4\,|\alpha + \gamma^2\beta|^2$, $C_{14} = |\gamma|^2\,|\tau|^4\,|\alpha + \beta|^2$]

if $|\Psi> = |A>|B>$ or $|A'>|B'>$ with weights $|\alpha|^2$ and $|\beta|^2$
(collapse)

$C_{13} = C_{14} = |\tau|^4\,(|\alpha|^2 + |\beta|^2)$ for $\gamma = e^{i\pi/2}$

[for general γ : $C_{13} = |\tau|^4\,(|\alpha|^2 + |\gamma|^4\,|\beta|^2)$,
$C_{14} = |\gamma|^2\,|\tau|^4\,(|\alpha|^2 + |\beta|^2)$]

'C_{13}' denotes the coincidence rate between counters '1' and '3', etc.

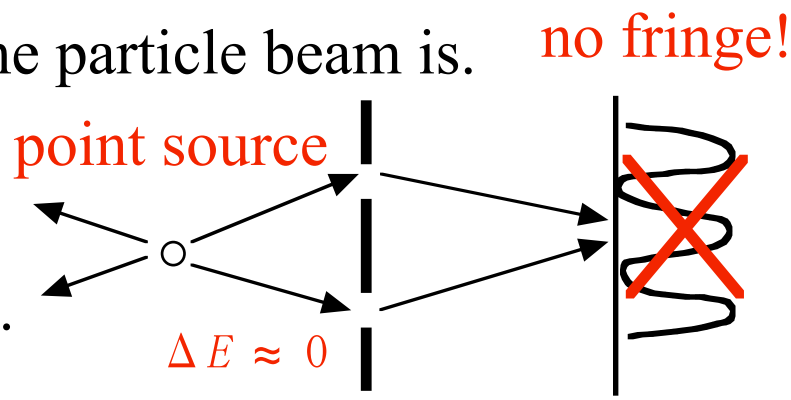


If we observe only the particle A, we must calculate $|\langle \boldsymbol{r}_1 | \Psi \rangle|^2$ by integrating over the position of the particle B.

$$|\langle \boldsymbol{r}_1 | \Psi \rangle|^2 = |\alpha|^2 |\phi_{\mathrm{A}}(\boldsymbol{r}_1)|^2 \langle \mathrm{B}|\mathrm{B}\rangle + |\beta|^2 |\phi_{\mathrm{A'}}(\boldsymbol{r}_1)|^2 \langle \mathrm{B'}|\mathrm{B'}\rangle + 2\mathrm{Re}[\,\alpha^* \beta\ \phi^*_{\mathrm{A}}(\boldsymbol{r}_1)\ \phi_{\mathrm{A'}}(\boldsymbol{r}_1) \langle \mathrm{B}|\mathrm{B'}\rangle\,]$$

Assuming the orthonormality of the wavefunction of the particle 2, interference term vanishes because $\langle \mathrm{B}|\mathrm{B'}\rangle=0$.

Then no interference fringe appears however small the source (collision region) size is, and however monochromatic the particle beam is.



This is not because the w.f. collapsed, but just **<u>because of the entanglement of two particles</u>**.

With low-energy electron collision and electron biprisms, we can prepare to confirm the dissapearance of the fringe[2].

[2] K. Toyoshima et al., Czech. J. Phys. Vol.56 (2006) 1361.

Thin crystal film as a beam splitter.

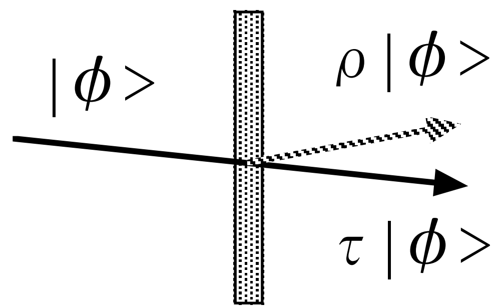
10-nm thick self-supporting Si crystal is reported[3].

mean free path is 3.2nm for 2.5keV electron.

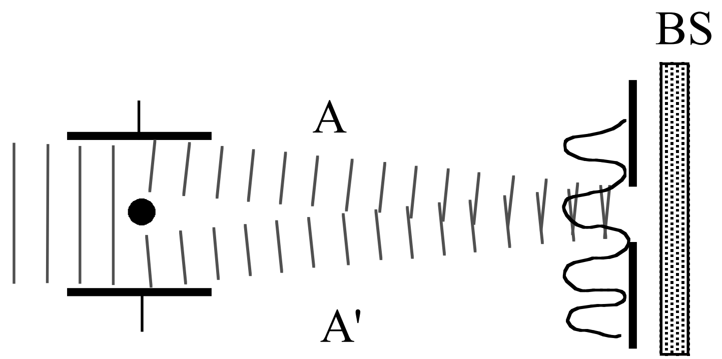
(attenuation to 4.4% after 10nm film)

$\rho = \gamma \quad \tau$

- smallest Bragg diffraction angle: $2\,\theta = 4.49^{\circ}$
- relative phase (γ) : no data availavle, but supposed to differ from zero significantly[4].



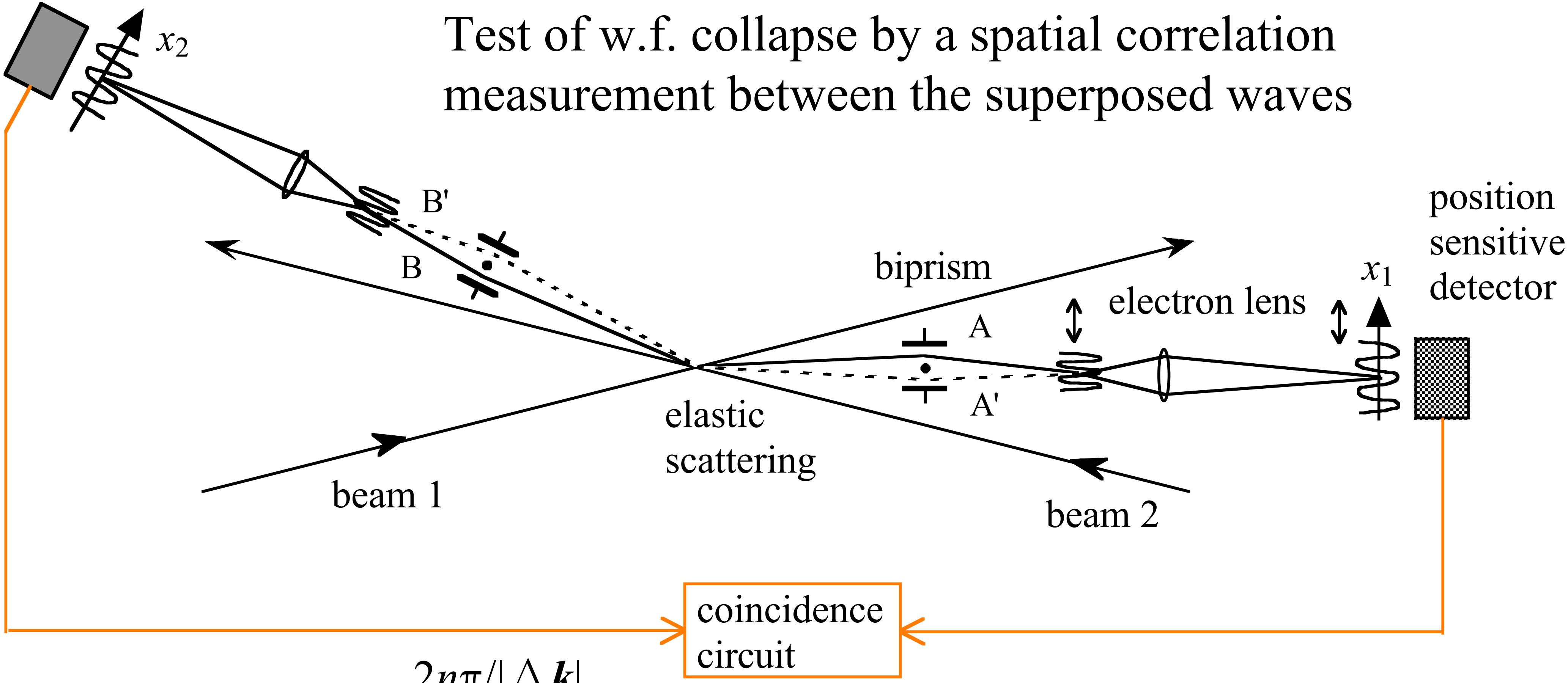
Fatal demerit: only single fringe line should be selected to hit the beam splitter. $\rightarrow$ <u>too small intensity</u>.

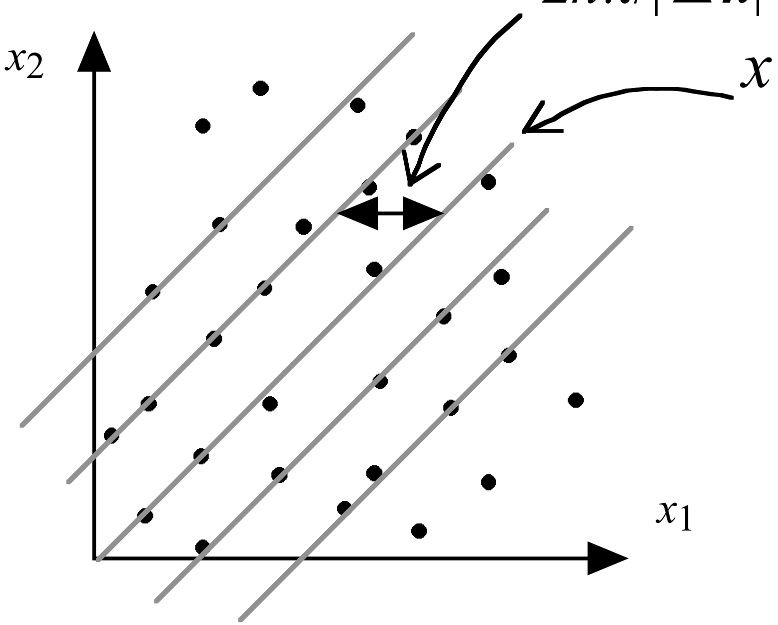


[3] S. J. Utteridge et al., Applied Surface Science, Vols 162-163, 1 Aug. 2000, P. 359-367

[4] Phase shift values for Si single atom at E_e=10kev are tabulated in "International Tables for X-ra Crystallography, vol. IV.

Test of w.f. collapse by a spatial correlation measurement between the superposed waves





(for simplicity, $\alpha = \beta = 1$ is assumed)

$$|\langle \boldsymbol{r}_1, \boldsymbol{r}_2 \mid \Psi \rangle|^2$$

$$= |\phi_{\mathrm{A}}(\boldsymbol{r}_1)|^2 |\phi_{\mathrm{B}}(\boldsymbol{r}_2)|^2 + |\phi_{\mathrm{A'}}(\boldsymbol{r}_1)|^2 |\phi_{\mathrm{B'}}(\boldsymbol{r}_2)|^2$$

$$+ 2 \cos[\, |\Delta \boldsymbol{k}| (x_1 - x_2) \,]$$