Interaction free measurement
CONSTRUCTIVE INTERFERENCE

DESTRUCTIVE INTERFERENCE
watched pot never boils

Something you are waiting for will not happen while you are concentrating on it.

Don't just sit there staring at the phone while you wait for Lucy to call. A watched pot never boils.
• imaging live cells

• x-ray without exposing radiation

• imaging Bose-Einstein condensate without disturbing

• imaging quantum states like Schrödinger’s cat
FIG. 3. Polarizing Mach-Zehnder interferometer. PBS denotes the polarizing beam splitter and $\lambda/2$ the half-wave plate at 670 nm. The locking laser (not shown) entered from the top port of the first PBS and exited from the side port of the second.

TABLE I. Object widths: inferred from “interaction-free” and normalized transmission scans, measured with microscope and diffraction. The uncertainty of the widths from the IFM and transmission scans are approximately ±1%, except for the cloth filament where they are approximately ±2%.

<table>
<thead>
<tr>
<th>Object</th>
<th>Width inferred from IFM scan ($\mu$m)</th>
<th>Width inferred from transmission scan ($\mu$m)</th>
<th>Width measured by microscope ($\mu$m)</th>
<th>Width measured via diffraction ($\mu$m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thin metal wire</td>
<td>95.3</td>
<td>96.6</td>
<td>95.5±1.6</td>
<td>97.0±0.5</td>
</tr>
<tr>
<td>Thick metal wire</td>
<td>160.2</td>
<td>162.7</td>
<td>159.1±2.3</td>
<td>159.5±2.0</td>
</tr>
<tr>
<td>Cloth filament</td>
<td>16.6</td>
<td>16.3</td>
<td>12.6±0.6</td>
<td>15.4±1.2</td>
</tr>
<tr>
<td>Human hair filament</td>
<td>22.8</td>
<td>24.7</td>
<td>25.1±0.9</td>
<td>26.2±0.6</td>
</tr>
<tr>
<td>Thin optical fiber</td>
<td>125.7</td>
<td>123.9</td>
<td>123.5±1.9</td>
<td>123.2±3.6</td>
</tr>
<tr>
<td>Thick optical fiber</td>
<td>208.0</td>
<td>207.5</td>
<td>207.9±3.0</td>
<td>208.3±2.5</td>
</tr>
<tr>
<td>Slit</td>
<td>12.5</td>
<td>13.1</td>
<td>N.A.</td>
<td>19.2±1.2</td>
</tr>
</tbody>
</table>
FIG. 4. Transmission and interaction-free images of various objects: (a) knife-edge, (b) metal wire, (c) cloth filament, (d) human hair, (e) thin optical fiber, (f) thick optical fiber, and (g) slit (the absence of an object). Note the variation in scale on position axes.
electron microscopy by interaction free measurements

- problem: sample damage induced by energetic electrons
b. Black Pixel  White Pixel

\[ t = 0 \]
\[ t = \frac{1}{2} \tau_c \]
\[ t = \tau_c \]
\[ t = \frac{3}{2} \tau_c \]
\[ \vdots \]
\[ t = N \tau_c \]
FIG. 2: (color online) Accuracy of interaction-free imaging and probability of electron scattering from the imaged object in the presence of decoherence. a. The solid (blue) and dash-dot (red) curves are plots of the imaging accuracy $\eta$ and the probability of scattering $P(\text{scat})$ versus $N$, respectively. The squares show points of maximum accuracy and corresponding values of scattering probability. The $\alpha^{-1}$ values $4.4 \times 10^3$ and $4.4 \times 10^5$ correspond to 100 KeV electrons circulating a ring of radius $R = 1$ cm and 1 mm respectively with a decoherence time of $\tau_D = 1 \mu$s. b. The solid (blue) and dash-dot (red) curves are respectively the maximum values of $\eta$ and the minimum values of $P(\text{scat})$ as functions of $\alpha^{-1}$.

FIG. 3: (color online) Multilayered structure equivalent to the v-shaped trap arrangement but more suitable for microfabrication. Black and dark gray (red) rectangles are grounded and RF electrodes (gold), respectively, and light gray (green) is insulating SiO$_2$. The effective potential $U_{\text{eff}}(r, z)$ is superimposed on the structure; dark (blue) and light (red) shades are low and high potentials, respectively, and white regions have potentials $> 20$ meV. RF voltage in this example is driven at 10 GHz with a magnitude of 2 V. The dimensions are $b = 48.5 \mu$m, $a = 24 \mu$m, and $d = 50 \mu$m. The electrode width and spacing are 4 $\mu$m. The inset shows an expanded view of the double-well. Near the trap minima the potential is harmonic with characteristic frequencies of $f_r, f_z = 33$ MHz, yielding a tunneling rate of $\Delta' = 2\pi \times 14$ MHz and an electron spot size (i.e. resolution) of 19 nm and 1.4 $\mu$m in the $\vec{r}$ and $\vec{z}$ directions, respectively (accounting for $B_0 = 1$ T for $R = 1$ mm).
Quantum Seeing in the Dark

Quantum optics demonstrates the existence of interaction-free measurements: the detection of objects without light—or anything else—ever hitting them

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