Hot, Dense Plasmas Give High-Resolution Radiographs of Flies

The fact that high temperature plasmas radiate x-rays is a well-known problem for fusion plasmas consisting of hydrogen isotopes that contain impurities. For this reason, impurities that might be sputtered, evaporated or desorbed from the chamber walls must be maintained at a concentration below 1%. However, if a hot dense plasma is localized to a small spot (much less than one-thousandth of an inch in diameter), then the x-rays it emits can be used for high-resolution radiography. That is exactly what is being done at Cornell University with a pulsed plasma called the X pinch.

An X-pinch plasma is generated by passing a very short duration 100,000 ampere current pulse through two metals wires, each of which is about one half inch long and one thousandth of an inch in diameter, that cross and touch at a single point in the form of an X. The huge current causes the wires to explode and form a plasma, but the magnetic field from the current confines the plasma near the original cross point of the wires, forming a plasma column. As the current increases in the plasma, so does the magnetic field, and the plasma column unstably implodes towards its axis, producing one or two extremely small, hot plasma points from which a burst of x-rays is emitted. The plasma then flies apart even faster than it comes together. These stages of X-pinch plasma development are illustrated by the six radiographs shown in Figures 1a-f, all made with molybdenum wires, in which the times given for each frame are relative to the moment the X pinch shown emitted its x-ray burst. Thus, the first frame is an image of an X pinch 6.1 billionth of a second (ns) before it emitted its x-ray burst, etc. (Each of these radiographs was obtained using another X pinch as the x-ray source. They were obtained on film using a thin titanium window to limit the x-ray energy range that reached the film.) Figure 1g shows that the radiographs in Figures 1a-f are only a small portion of the original wires used to make the X pinch.

Detailed studies (to be reported at this conference in an invited paper by T. A. Shelkovenko, UI2.001, and a contributed paper by D. B. Sinars et al., RP1.104) indicate that X-pinch plasmas reach densities almost as high as solid density, and temperatures are as high as 10,000,000 Centigrade degrees. However, they are much less than a thousandth of an inch in size, and they last less than one billionth of a second at that small size and high density.

Because the X pinch is such a tiny, but very hot and dense plasma, it can be used as a point-source of x-rays. Therefore, it can be used to generate extremely high-resolution radiographs of very small objects. Figures 2a and b show radiographs of a common house fly and a fruit fly. Figures 3a-b show enlarged portions of the fly images to illustrate the high resolution. The x-ray energy range allows the radiographic images to be high-contrast even though the flies absorb only a tiny fraction of the radiation by a method (phase-contrast imaging) to be presented in a paper by Pikuz et al. (RP1.101).

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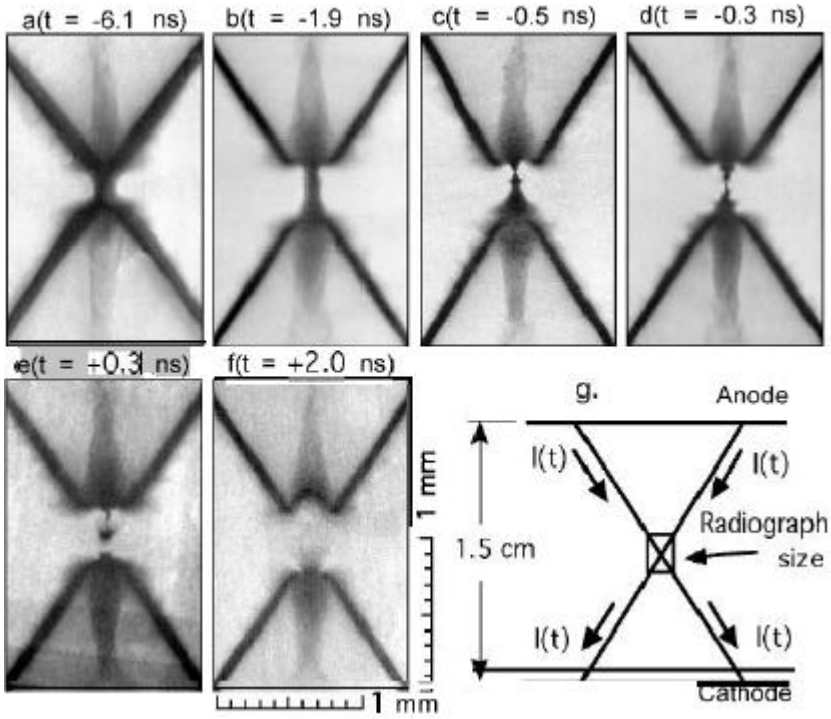

Fig. 1 A series of radiographs of 25 μm Mo wire X pinches

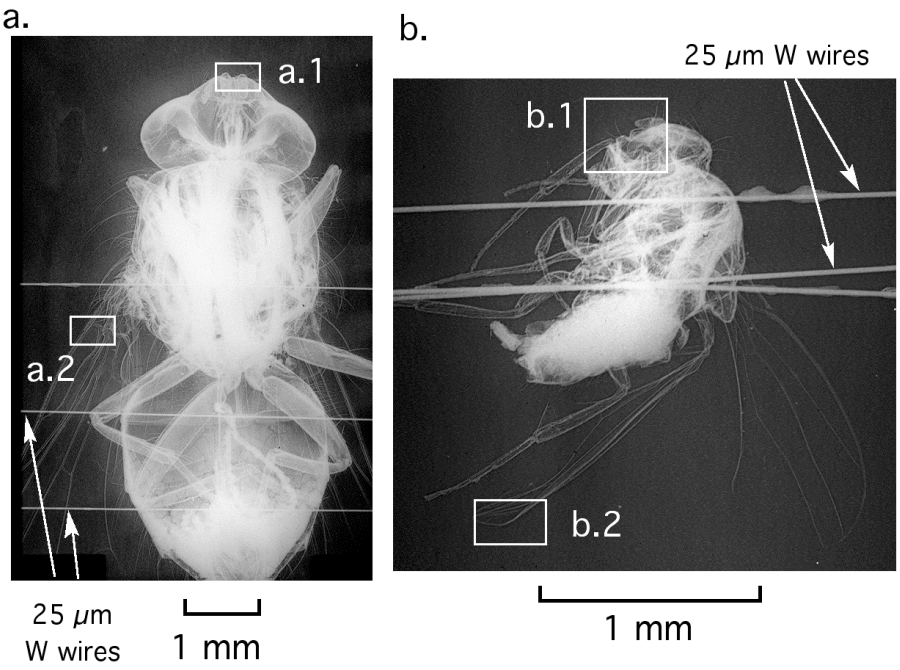

Fig. 2 Radiograph images of House fly (a) and Fruit fly (b)

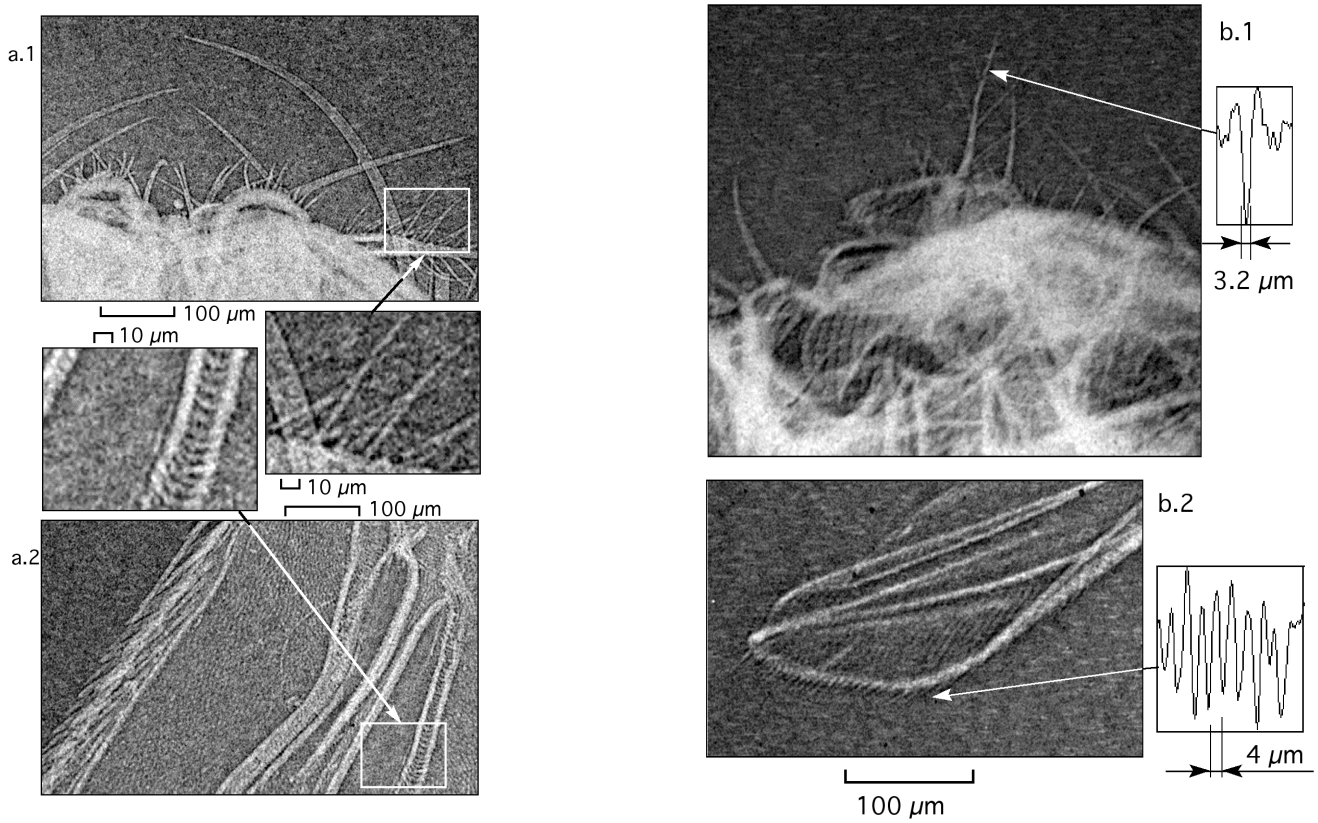

Fig. 3 Enlarged parts of the fly images. Parts are labelled as in Fig. 2.