International Cooperation in the Development of Proton Radiography

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Summary: Efforts around the world are working to improve the technique of proton radiography and new applications are being discovered each year. This development can only be pursued at high energy proton accelerator facilities, limiting the base from which new capabilities will be developed. A strong collaboration between these facilities will result in the fastest and fullest utilization of this new capability.

Introduction

In the decades following the discovery of the penetrating capability of x-rays in the late 1800's novel applications of this new technology were discovered every year. These inventions ranged from the medical applications still in use today to more esoteric applications, such as x-ray radiographs to determine proper shoe size at the shoe store. These new applications demanded improvements in the techniques, such as the development of x-ray tubes to generate high fluxes of x-rays and high resolution x-ray detectors. A century later, these improvements continue. For example, high efficiency solid state detectors are reducing the dose received in the dentist's office and the DARHT facility at LANL is providing new capabilities in flash radiography studies of dynamic systems.

Proton radiography, which was first investigated in the late 1900s, is undergoing the infancy of a similar type of development. New applications are discovered every year along with improvements to the technique, which then enable further applications. Proton sources capable of providing useful beams for proton radiography, however, are more difficult and expensive to build. Luckily previous investments in nuclear and high energy physics have provided proton sources around the world, which are ideally suited for applications of proton radiography. Strong collaboration on the development of proton radiography between scientists and engineers who have access to these proton sources will be a key to the full application of this new technology in the decades to come.

Technology Development and Applications

Los Alamos National Laboratory has developed the technique of proton radiography as a flash radiography system for the study of dynamic systems. These studies have focused on measuring fundamental material properties (equation of state, strength, phase transitions…) as well as the physical processes important in predicting the hydrodynamic flow of these materials at high velocity pressure and density (instabilities such as Richtmyer-Meshkov, Rayleigh-Taylor and Kelvin-Helmholtz). Typically this type of experiment requires the development of high resolution radiography systems. Therefore, the proton radiography effort at LANL has focused on improving resolution. This effort led to the development of a magnifier system, shown in Figure 1, which was used to generate the radiographs also shown in Figure 1. The multi-time, high-resolution capability of proton radiography, as it has been applied to the study of material strength at high strain-rate, is a good example of the unique capability that proton radiography provides for the study of dynamic materials science.

A similar series of experiments have been performed at the Institute for High Energy Physics at Protvino, Russia. The technique used to form and collect the proton radiographs are very similar, although the proton source is very different. At Los Alamos, an 800 MeV linac is used to generate the protons, at Protvino a synchrotron is used to generate the 50 GeV protons, which are used for these experiments.

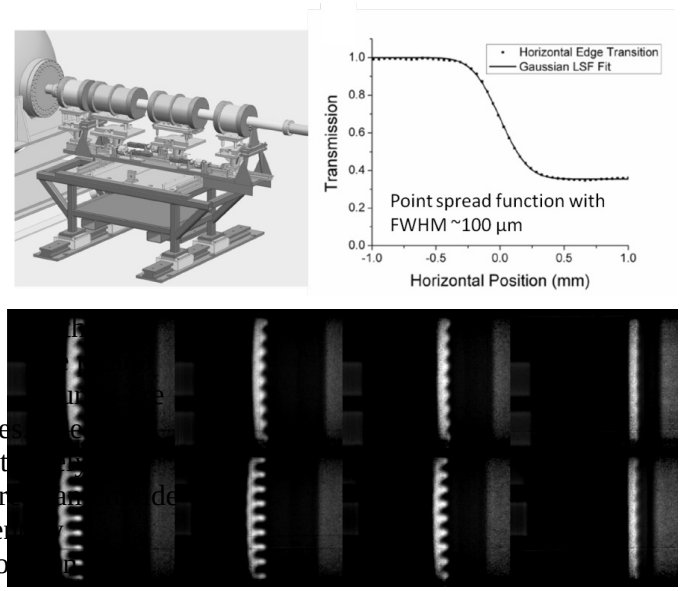
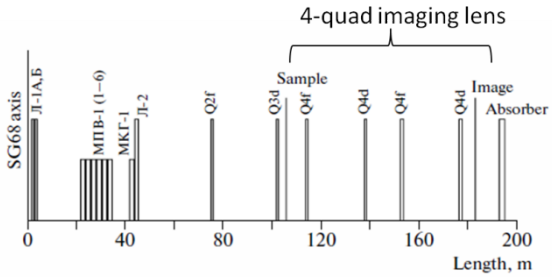


Figure 1: (top, left) drawing which shows the magnifier system that was developed to provide 100 micron resolution for dynamic experiments (top, right). This system was developed to provide adequate radiographic resolution to study the early to late time evolution of Rayleigh-Taylor growth for the estimation of material strength (bottom).

different, they are complementary in their capabilitie
structure of protons from a linac proton source is ext
flexible, while the high energy of a synchrotron sour
remarkable resolution. These similar, yet, complime
capabilities provide a unique opportunity for collabo

Conclusions

Proton radiography has opened new windows of research in the study of dynamic material processes. New applications and improvements to this technique are being discovered yearly by a small community of scientists and engineers in the US and Russia. Collaboration between these communities could speed the development of this diagnostic technique for execution of experiments of mutual interest as well as applying this diagnostic to research in new areas. The complementary nature of these two can provide opportunities for shared facility collaboration on the study of dynamic material properties, technology development and novel applications.



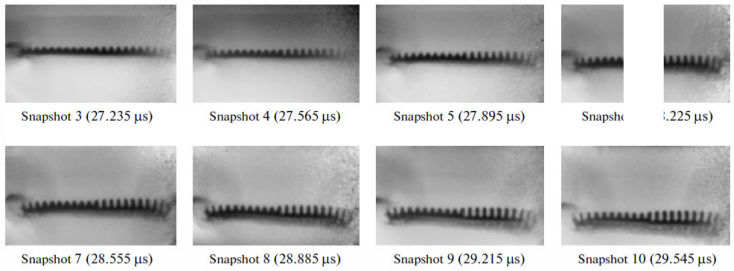


Figure 2: Experiments similar to those shown in figure 1 have been performed at the Institute for High Energy Physics in Protvino, Russia. This series of radiographs allowed the measure of two growth rates with two different amplitudes of the initial seeding perturbation. Inst. & Exp. Techn., 53, 3 (2010)

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