TESTING OF LASER-DRIVEN RESONANT ACCELERATING-STRUCTURES POSSESSING SUB-WAVELENGTH PERIODIC FEATURES

N. Vartanian, G. Travish, E. Arab, UCLA, Los Angeles, CA 90095, U.S.A.

Abstract

The Micro-Accelerator Platform, a laser-driven accelerating device measuring less than a millimeter in each dimension, has a variety of applications in industry and medicine. The structure consists of two parallel slabs, with each possessing reflective surfaces and with one having periodic slots which allows transversely incident laser light to enter the gap between the two planes. The resonance of the electric field created in the gap can be measured indirectly through the spectral response of the device. Using a combination of an interferometer and a fiber coupled spectrometer, prototype structures are aligned and measured. With the aid of a nanometer-accuracy positioning device, the bottom slab (a mirror) is aligned with the top slotted-structure. The interferometer and a low power laser are used to position the slabs. A 800nm Titanium-Sapphire oscillator with a bandwidth of greater than 100nm is used for the spectral measurements. The spectra of both transmitted and reflected beams have been measured for a number of structures and are compared to simulation results. Various improvements to the initial measurement system as well as alternative future approaches are discussed.

INTRODUCTION

The Micro-Accelerator Platform (MAP) is a periodic resonant structure comprised of two parallel dielectric reflective surfaces[1]. In the final design, the bottom slab will be a dielectric mirror and the top slab will be a short Distributed Bragg Reflector (DBR) in which there are periodic slots through which laser enters. The gap between the two slabs is approximately a laser wavelength in height (Fig. 1).

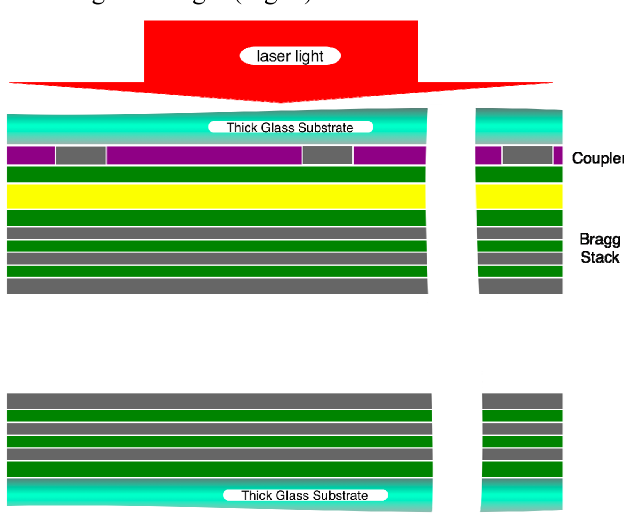


Figure 1: A cross-section of the fully-relativistic version of the Micro-Accelerator Platform.

Beams created with this micro-accelerator have many potential applications in medicine and industry, such as cancer treatment [3]. Due to its size, the MAP could be inserted into the body through an endoscope and placed adjacent to a tumor (Fig. 2), minimizing the damage to the surrounding tissues that would have been caused through external beam radiation therapy.

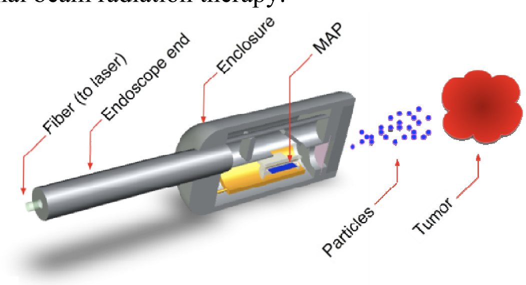


Figure 2: Conceptual representation of an encapsulated Micro-Accelerator Platform for medical applications. At one end (left), the MAP is connected to a fiber which provides the power. On the other end (right), particles are produced which are applied to destroy the tumor.

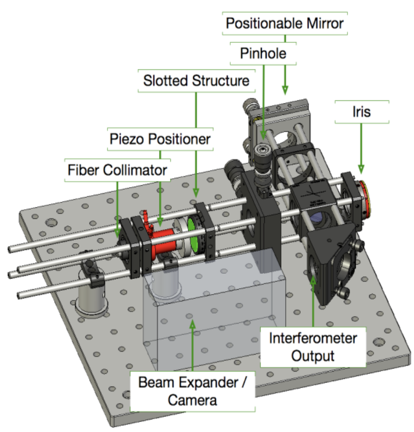
Before developing the full structure, cold test models where fabricated using patterned metallic layers in place of the DBR structures. As described in the next section, tests were performed to determine the response of these prototypes. The electric field between the two reflective slabs and the presence of a resonance can be observed by measuring the reflected and transmitted components of a laser beam incident on the MAP [2,3].

MEASUREMENTS

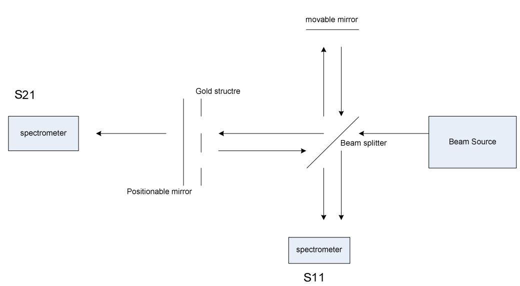
The goal of the work described in this paper was to measure the reflected and transmitted spectra from test structures illuminated by a broadband (750-850 nm) laser, and compare them with the simulations. The measurements are performed with the aid of a purpose-build test stand consisting of an interferometer and a spectrometer (Fig. 3). The test structure consisted of a slotted gold coated fused silica substrate and a conventional laser mirror. The mirror was mounted on a 3-axis, nanometer resolution positioner. The interferometer and a low power Helium-Neon laser are used for alignment purposes. The beam splitter divides the laser into two components: reflected (45%) and transmitted (55%). The transmitted beam (S21) passes through the gold slotted structure (installed on a 100 micron pinhole) and the piezo-positioned mirror. The transmitted spectrum from both surfaces is measured by the spectrometer. The portion of the beam that reflects back from these two surfaces returns to the beamsplitter and combines with the reflected beam from the beamsplitter. The reflected signal (S11) can also detected at the spectrometer, by repositioning the fiber coupler.

For the relative alignment of the two reflective surfaces, the bottom mirror position is controlled by a piezo-positioning device “tip”, “tilt”, and “z” degrees of freedom. Each axis has a maximum range of 12 microns, which exceeds the errors in both the surface figure and initial (static) alignment of the two slabs. The positioner control and spectrometer output are both connected to a computer and manipulated using LABView.

A high power Titanium-Sapphire laser is used for spectral measurements. For optimal results, neutral density optical filters, a polarizer, and a half wave-plate were also used.



a.



b.

Figure 3: (a) The design of the combined interferometer/spectrometer set up. (b) the beam travel path. The bench-top system is aligned using a low power laser. A high power broadband laser is used for data acquisition.

INITIAL RESULTS

Using the bench-top system described above, tests were performed with first the metallic slotted structure and no mirror. The slotted structure alone acts as a diffraction grating, and therefore has distinct transmission and reflection spectra. Moreover, by removing the bottom mirror, the alignment challenges are simplified. This simplification comes at the expense of not being able to measure resonant buildup of the field in the full structure.

The transmitted spectrum (S21) with only the gold structure slab installed was first measured (Fig. 4).

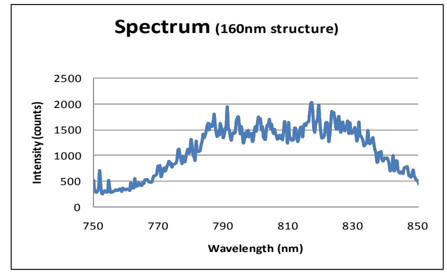


Figure 4: Transmitted Spectrum (S21) of a metallic slotted structure.

The transmitted (S21) spectrum of Fig 4 was then subtracted from the input laser spectrum. The result (Fig. 5) show qualitative similarity to the simulations for the transmitted spectra (Fig. 6).

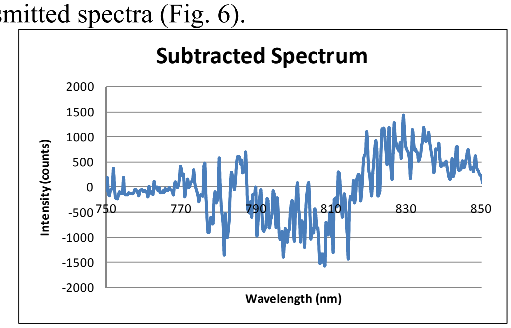


Figure 5: Laser spectrum subtracted from the spectrum of the transmitted beam through gold structure.

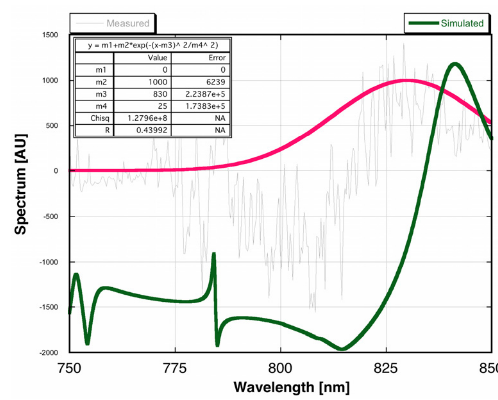


Figure 6: Simulations(green), smooth curve(pink), and data spectrum (grey) of transmitted beam through the 160nm gold structure are overlapped for comparison.

Additional measurements were made of the reflected spectrum of the slotted structure, but with poorer correlation to simulation. Measurements were also attempted on the full structure, with the bottom mirror in place, and these resulted in no distinct resonant lines, as would be expected from simulations.

Further analysis of data showed two significant sources of the lack of correspondence with expectation: in all cases, the resolution and repeatability of the spectrometer appeared to be inadequate for the ~1nm features expected; and, in the case of the full structure, the commercial mirror used was not similar to the model used in the simulations.

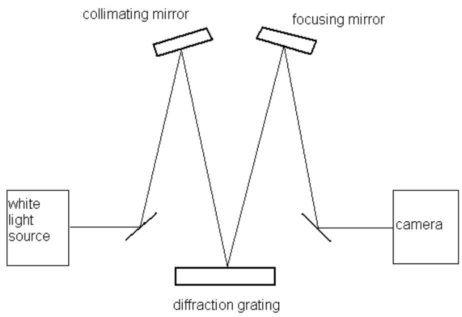


Figure 7: The new assembly consists of the camera, the high resolution spectrometer, and the mercury lamp as the white light source.

New Testing Method

In order to address the shortcomings above, a new testing method is being designed to measure the reflected and transmitted beams.

A white light source is now being used. This source offers a broader bandwidth than the titanium sapphire laser, and avoids the coherent interference that can complicate measurements performed with a laser. The new testing method is comprised of a mercury lamp as the white light source, a camera for detection, and a high resolution spectrometer (Fig. 7). The camera, combined with a quarter-wave spectrometer, should allow for sub-nm resolution spectral measurements.

CONCLUSION

The first measurements on the optical-scale micro-accelerator platform were performed. A number of shortcomings to the measurement approach were uncovered, and a new test-bench was designed. Future work will seek to find resonance in the micro-accelerator structure.

REFERENCES

[1] J. B. Rosenzweig, et. al., Phys. Rev. Lett. 74, 2467 (1995).

[2] G. Travish, et. al. in *procceedings of Particle Accelerator Conference* (2008).

[3] Yoder, R. B., et. al. in *proceedings of European Particle Accelerator Conference* (2007).