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Multigigahertz beam diagnostics for laser fusion*

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Abstract

A system to make ultra wideband measurements of fast laser pulses and their induced target interactions at a distance of approximately 38 m from the target location is discussed. The system has demonstrated an overall bandwidth of 3 GHz with projected unfolding to 4 GHz. This system allows high resolution temporal history diagnostics in a remote location providing high EMI and radiation immunity.

Introduction

In laser fusion target interaction studies precise measurements of driving pulse characteristics as well as target implosion parameters require diagnostic channels to have electrical bandwidths of several gigahertz.[1] In order to achieve such high-signal bandwidths, a first approach would be to restrict any electrical signal transmission line length to the shortest possible distance. This technique, however, imposes many restrictions on the quality of data that can be obtained. There exists a severe amount of time-dependent background radiation in the form of hard and soft x-rays that can interfere with diagnostic electronics that are in close proximity to the target area and the final laser power amplifiers of the Helios Carbon Dioxide Laser Facility.[2] The recently developed generation of multigigahertz real-time oscilloscopes used for data recording are particularly susceptible to this x-ray flux.[3] These oscilloscopes employ a micro channel plate electron multiplier that, when exposed to a radiation source, scintillate, "washing out" the actual pulse shape data. The EMP of the imploding target together with the electrical noise of the laser amplifiers create an area of relatively high EMI in the locale of the target interaction area further complicating other electrical measurements.

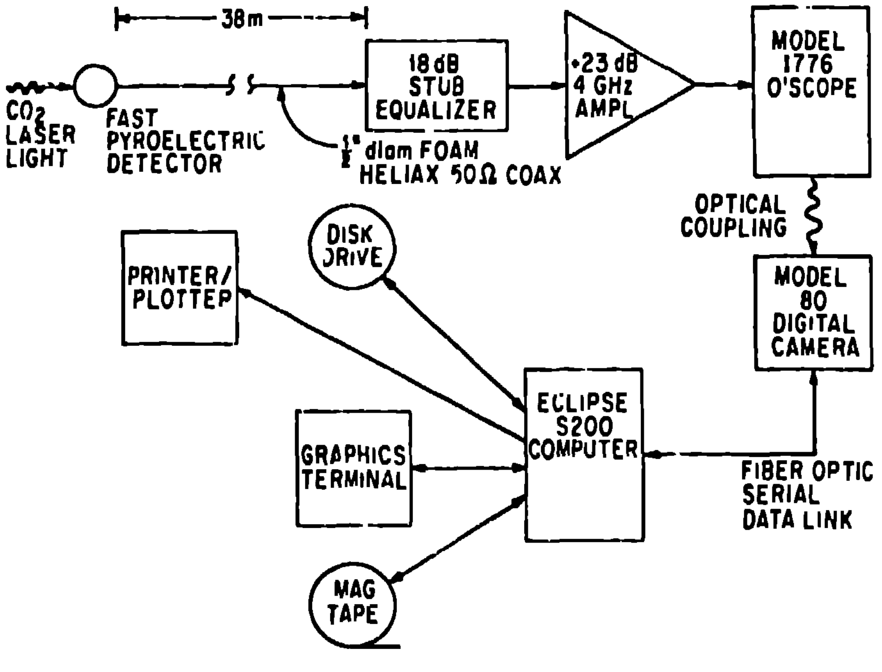

Figure 1. System Schematic

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It is an additional requirement that common timing between the driving laser pulses and the target induced data be available on a time scale of less than approximately 50 ps. This requires that the fast laser pulse shape data be located near the fast target produced data in order to apply timing information on the various oscilloscope channels. Operational constraints limit the amount of space that can be allocated for diagnostic equipment near the target chamber thereby producing a less-than-optimal environment for pursuing actual diagnostic equipment operation. These factors, coupled with the certain need for future expansion of diagnostic capabilities, have prompted us to develop a method of making multigigahertz bandwidth diagnostics at a distance of ~ 38 m from the target interaction point.

Description of the system

As a demonstration of feasibility we chose to measure the temporal history of the laser pulse itself. This signal was chosen because it was known to provide a suitably fast pulse for system testing, and it could be easily compared with the results obtained by a similar system located ~ 4.5 m from the optical detector. Refering to Fig. 1, the first Fresnel reflection from the entrance window to the target chamber is sampled and focused onto a fast ($t_r \leq 50$ps) pyroelectric detector.[4] This signal is then transmitted via 1/2 inch diameter, 50 ohm, foam dielectric coaxial cable to an amplifier with a bandwidth of ~ 4GHz and a voltage gain of ~ 23dB. The signal is then recorded on a Los Alamos National Laboratory built model 1776 high speed oscilloscope. The system has a raw (unequalized) bandwidth of ~ 250 MHz (Fig. 2). Almost all of the bandwidth degradation in the system is due to the coaxial cable attenuation at higher frequencies. In order to achieve the necessary wide bandwidth, an equalizer network was developed using 1/4 wavelength resonant stubs to compensate for the cable "roll-off". These equalizers in effect have a Fourier transform which is the complex reciprocal of the unequalized system as can be seen in Fig. 3. Also shown in Fig. 3 is the frequency domain convolution of the equalizer and the unequalized system response. The result of this convolution is the predicted bandwidth of the system with the equalizer. In the case of the laser pulse temporal history channel, a bandwidth of ~ 3 GHz with an equalizer dc attenuation of 18dB was predicted. This 18dB loss, coupled with a 23dB gain in the the amplifier, should yield a system gain of ~ 5dB.

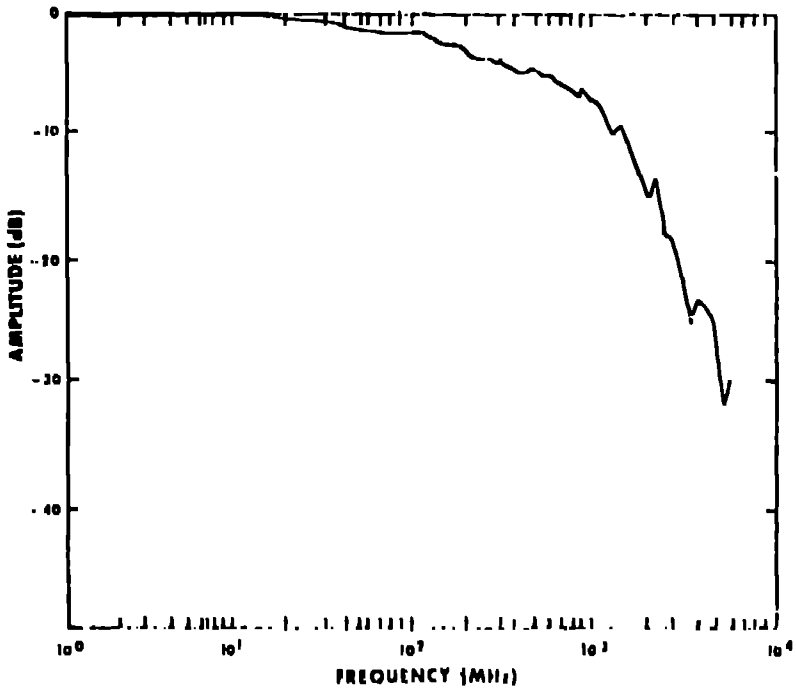

Figure 2. Unequalized system response.

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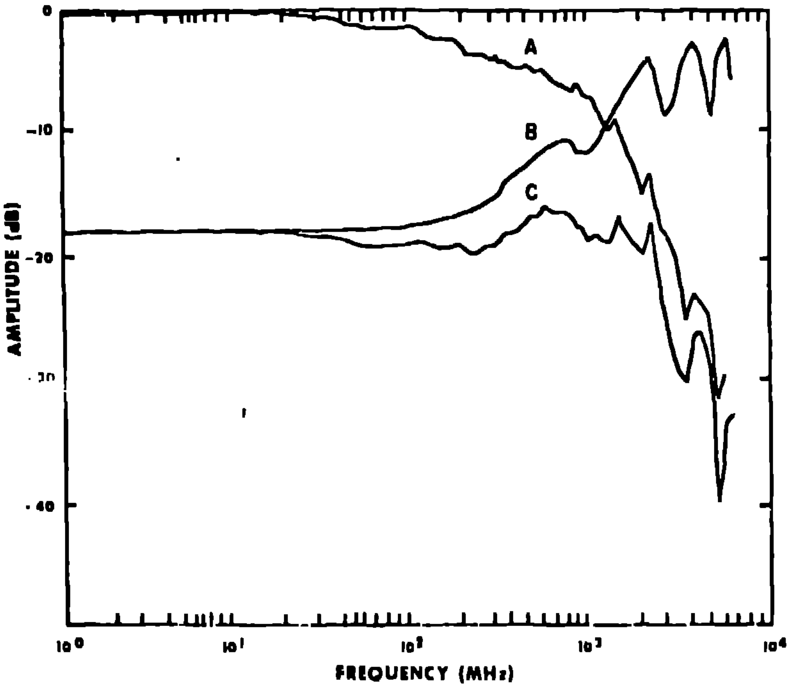

Figure 3. Predicted equalized system response
A - Unequalized system response, B - Predicted equalizer response, and C - Predicted system response.

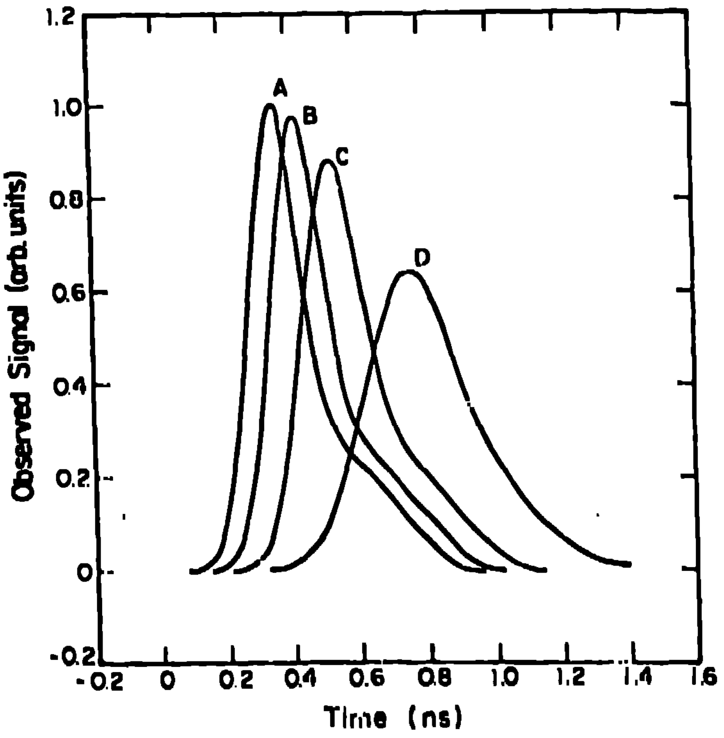

Figure 4. Effects of bandwidth on pulse shape
Input function A convolved with different Gaussian system bandwidths: B-7GHz, C-3GHz, D-1.3GHz.

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A system bandwidth of 3 GHz was chosen as a starting point by computer modeling of the system with a predicted optimal laser pulse shape as an input. Figure 4 shows the computer convolutions of this input pulse with various system bandwidths. A ratio of output to predicted input parameters of the laser pulse shape convolved through systems of different bandwidths is shown in Fig. 5. This simulation shows that for the parameters of signal peak amplitude and rise time, systematic errors of ≤ 10 percent are introduced at bandwidths above 3.5 GHz. Due to the difficulty of making accurate measurements of the unequalized system response at levels in excess of 20dB down from the half power point, we elected to equalize the system to 3 GHz and then employ an off-line, constrained deconvolution unfold of the data to achieve a data bandwidth of ~ 4 GHz.[5] In order to facilitate data reduction via this unfold method, a digital camera is being designed to read the oscilloscope trace and send the data to the central Helios facility computer system. The previously evaluated system tranform stored in the computer will then be used to perform the mathematical unfold for each individual channel of the data acquisition system.

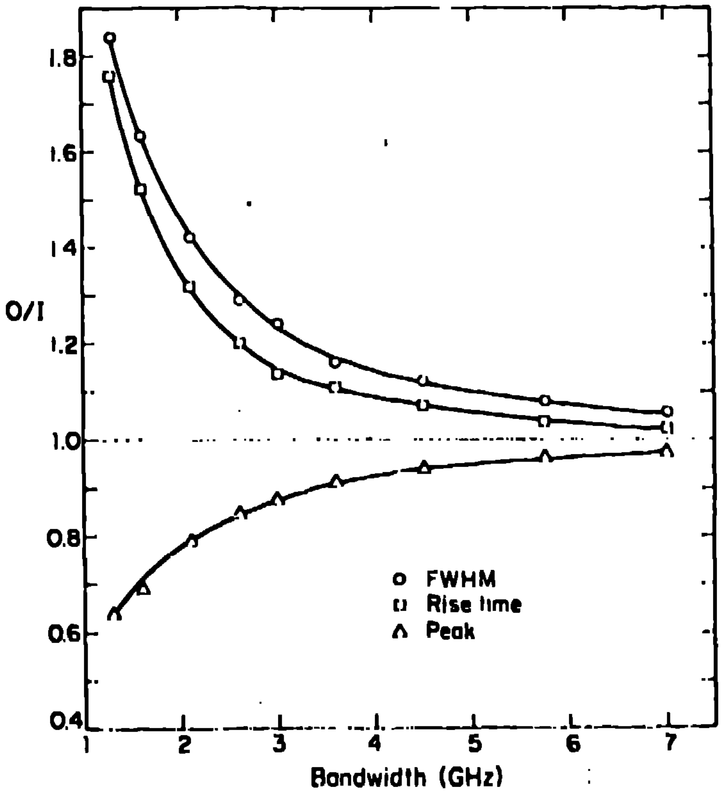

Figure 5. Pulse parameter system errors for various bandwidths.

The type of coaxial cable was chosen to be compatible with the proposed system bandwidth. Referring to Fig. 6, 1/2 inch foam dielectric cable was shown to have the lowest attenuation over the anticipated distance while providing a potentially wide enough bandwidth with equalization. It should be noted that the larger diameter cables, while having less attenuation, also allow high order TEM modes to propagate in the cable at reasonably low frequencies that produce "ringing" artifacts in the transmitted signal. Maximum equalizer attenuation (for the cable alone) was calculated as the point at which ± 45° of non-linear phase had been encountered in the Fourier transform.

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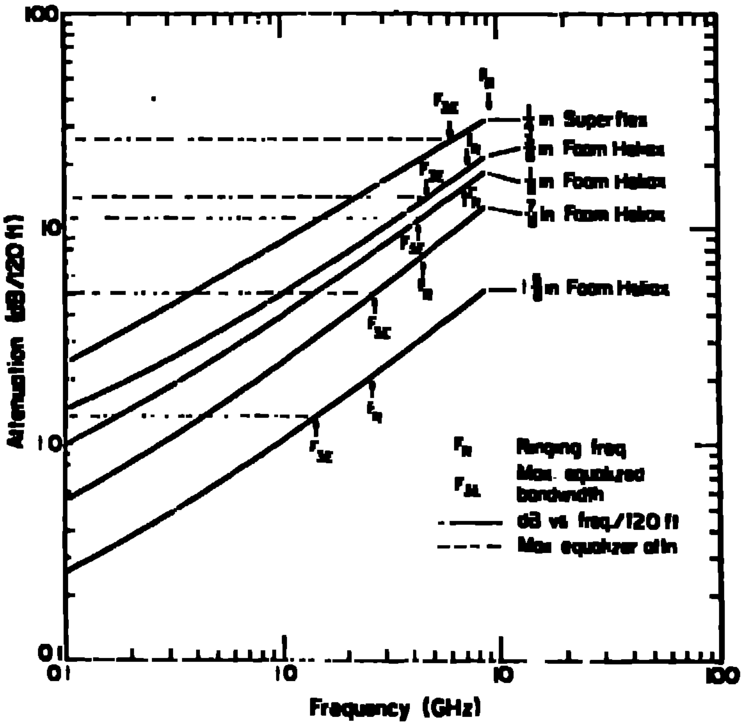

Figure 6. Coaxial cable response for 120 foot run.

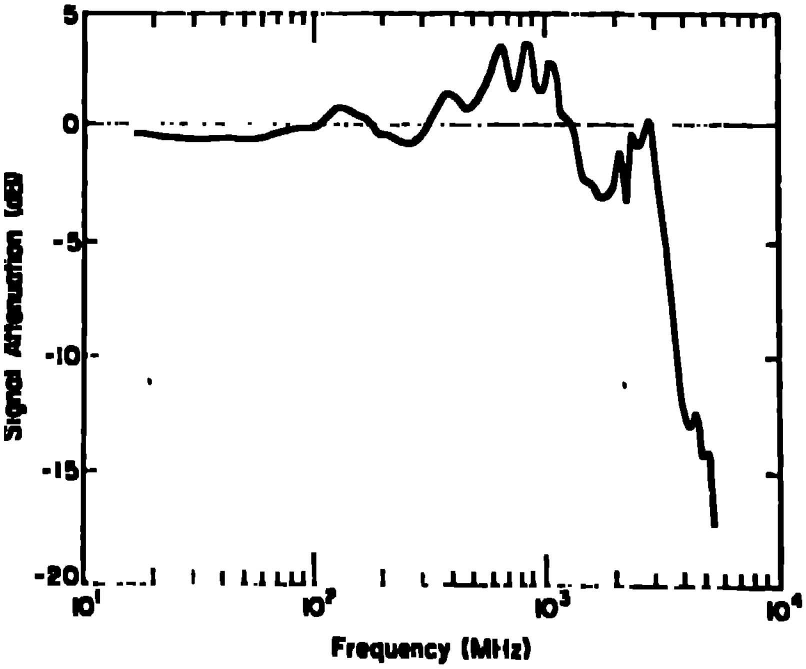

Figure 7. Measured system response.

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Results

The system described was constructed and a measurement of system bandwidth was made. By removing the detector from the system and driving the system with a 20 ps step function, the system bandwidth was determined to be ~ 3 GHz as predicted. Figure 7 shows the transformed time domain data. The gain of the system was measured and was found to be ~ 5dB.

The signal from the detector was then applied to a matched power divider, one output of which fed a "close-in" diagnostic recorder at approximately 4.5 m from the detector, and the other fed the system being tested ~ 38 m away. The bandwidth of the "close-in" system was known to be ~ 1.5 GHz.

Figure 8 shows the results of a laser shot as seen on both channels viewing the same detector as described. Although the laser pulse measured was not severely band limited by either recording system, some differences can be seen in the overlay. The major feature is the long tail appearing on the pulse shape of the "close-in" channel. This tail is attributed to the reduced bandwidth of the "close-in" channel caused by the ~ 4.5 m of 3/8 inch diameter foam dielectric coaxial cable used to connect the oscilloscope to the detector. Additional minor differences in the two recorded pulse shapes can be attributed to differences in the film-digitization methods employed. The "close-in" channel was digitized from Polaroid film on a digitizing pad which allowed for a gross undersampling of the recorded trace, whereas the remote channel was recorded on transparency film and then read on a 30X magnification film reader. This difference caused the "close-in" channel to seem to wash out some of the detail seen in the remote channel. However, for the parameters of rise-time, full width at half maximum, and peak amplitude, the comparison is remarkable.

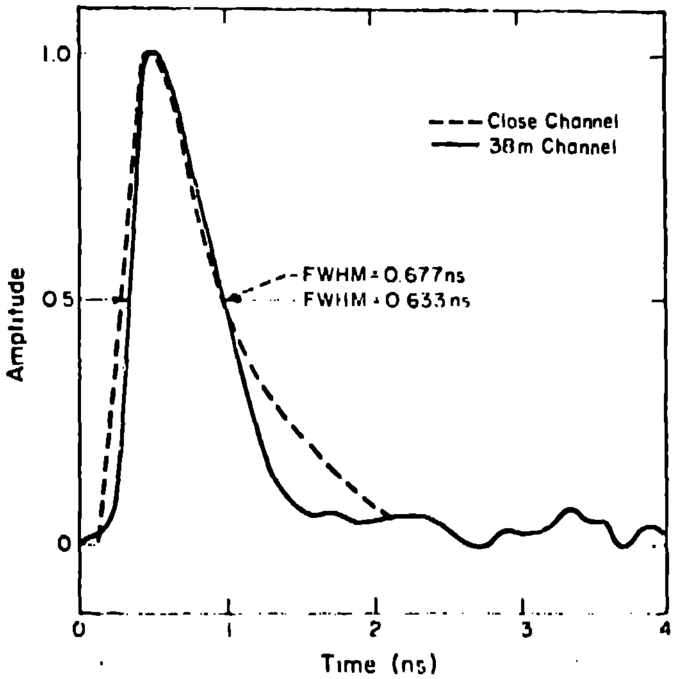

Figure 8. Laser pulse shapes.

Conclusions

A system capable of recording multigigahertz electrical signals from diagnostic detectors at a distance of ~ 38 m from these detectors has been demonstrated on the Helios Carbon Dioxide Laser Facility. This type of system provides a radiation and noise-free environment for the recording of fast, transient events produced by laser fusion. The system also allows for future expansion of diagnostic capabilities by not limiting diagnostic instrumentation to the immediate target-chamber area.

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Acknowledgments

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References

1. "Antares Target Diagnostics System Study," October 1979; P-14-79-U-200, Los Alamos National Laboratory internal document.
2. "Helios: A 15 TW Carbon Dioxide Laser Fusion Facility," R. L. Carlson, J. P. Carpenter, D. E. Casperson, R. B. Gibson, R. P. Godwin, R. F. Haglund, Jr., J. A. Hanlon, E. L. Jolly, and T. F. Stratton; Los Alamos National Laboratory report LA-UR-81-479, and to be published in the Journal of Quantum Electronics special issue on Lasers for Fusion, August 1981.
3. "A New High Speed Oscilloscope For Fast Plasma Diagnostics," V. T. Trexler, R. C. Smith, D. S. Metzger; IEEE International Plasma Physics Conference, 1979.
4. "A Single-Sweep 5 GHz Oscilloscope-Detector Combination For CO_2 Laser Pulse Measurements," E. J. Mclelland, J. S. Lunsford; IEEE J. Q. E., QE-13, 38D (1977).
5. "Predictable Unfolding In The Time Domain," E. K. Hodson; Los Alamos National Laboratory report LA-3830, September 1967.