MPS/LIN/MB/nc

MPS/LIN Note 75-8

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DISPOSITIF PERMETTANT L'OBSERVATION ET L'ACQUISITION DIGITALE DE LA FORME DES "BUNCHS" A LA SORTIE DU LINAC

M. Bourgeois et P. Têtu

I. GENERALITES

Pour le nouveau Linac, une insistance particulière est mise sur l'adaptation du faisceau aux différentes énergies [1] : action du double groupeur dans le LEBT; connaissance des caractéristiques du faisceau à 10 MeV, 30 MeV, 50 MeV rendent nécessaire une mesure des paquets de faisceau.

A 50 MeV une ligne de mesure spectrométrique donnera des informations sur le plan longotudinal pris globalement. L'observation d'un paquet discret reste toutefois souhaitable ne serait-ce qu'en vue de comparaison avec les mesures effectuées aux énergies plus basses.

Des capteurs ont été developpés et fonctionnent correctement [2-4], la visualisation sur oscilloscope reste toutefois assez pénible. On peut envisager une méthode sampling [5,6] qui par ailleurs n'a pas les mêmes avantages que la mesure "en un paquet".

Le dispositif que nous allons étudier utilise en grande partie du matériel existant chez "Tektronix" et son originalité résidue surtout dans le mode de stockage simultané de plusieurs "bunchs" pris tout au long de l'impulsion Linac sur la cible silicium d'un tube spécial.

Le nombre de "bunchs" observés n'est pas limité, on peut envisager raisonnablement de stocker 5 à 10 "bunchs" également répartis dans une impulsion Linac. Seule la mémoire tampon de sortie grossit en fonction du nombre de points à mémoriser.

Le stockage se fait en temps réel et la lecture se fait en 60 ms par un balayage vidéo, ce qui signifie que 60 ms après le passage du faisceau Linac on peut disposer de l'image de N "bunchs" sur un moniteur et des coordonnées digitales de tous les points.

II. PRINCIPE

Le signal détecté par une sonde rapide, d'un type existant au Linac, est appliqué sur les plaques de déflexion verticales du tube spécial que nous décrirons plus loin, via un tiroir standard d'accès direct 7A21N. Ce tube est formé d'une part d'un tube d'oscilloscope rapide (2 GHz) ayant un écran spécial constitué par un réseau de jonction P.N. et d'autre part par un tube type "Vidicon" ayant l'écran en en commun avec le tube précédent.

Le principe de fonctionnement est assez simple : la trace faite par le passage du faisceau d'électrons sur l'écran est mémorisée par l'écran lui-même et le tube de lecture effectue un balayage "vidéo" générant un "bit" chaque fois que le balayage touche un point activé de l'écran.

Le signal ainsi obtenu peut être simplement utilisé pour visualiser les "bunchs" sur un moniteur ou mémoriser et traiter digitalement par des interfaces Tektronix Camac ou PDP.11.

Le cycle écriture-lecture dure environ 60 ms ce qui rend impossible le traitement d'un "bunch" après l'autre au cours d'une impulsion Linac, mais il est possible de mémoriser plusieurs "bunchs" répartis le long de l'impulsion Linac et de les traiter en bloc après.

En utilisant la base de temps 7B92 il est possible de sélectionner un certain nombre de "bunchs" également répartis, et de synchroniser un générateur de tension en escalier, permettant le décalage vertical des traces "bunch" après "bunch" sur l'écran.

Une autre solution consisterait à stocker plusieurs bunchs sur une même marche d'escalier, cette solution est possible mais compliquerait probablement l'acquisition digitale des données.

III. REALISATION

1) Acquisition du signal

L'appareil de base utilisé est le "Transient digitizer R7912 Tektronix utilisant le tube "scan converter tube" décrit ci-dessous

A close-up look at the crt

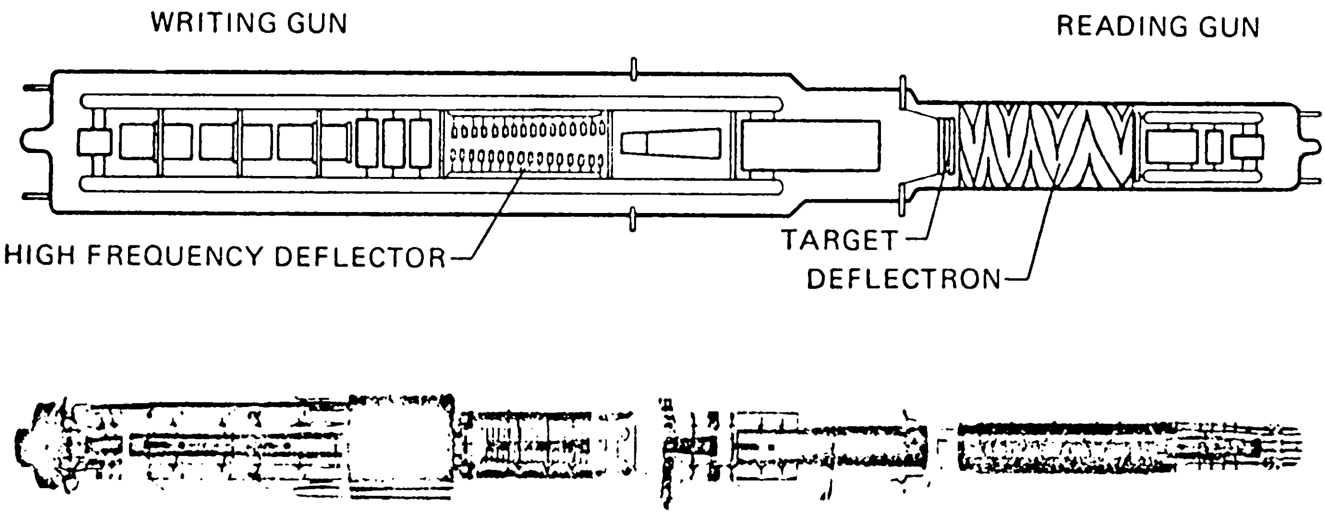


Fig. A. R7912 CRT.

Ce transient digitizer sera équipé de deux tiroirs standard de la série 7000 : le "direct access" 7A21N et la base de temps 7B92. Pour synchroniser le générateur de tension en escalier il faudra prélever à l'intérieur de la base de temps, ou à sa sortie, une impulsion de déclenchement.

Si l'on désire mesurer 10 "bunchs", soit 1 toutes les 10 µs, la tension en escalier aura une fréquence propre de 100 KHz. Cette tension pourra être mixée au signal d'entrée ou simplement appliquée sur l'une des entrées du 7A21 et le signal sur l'autre.

2) Lecture du signal

Le transient digitizer R7912 est équipé dans sa version standard d'un tube dont l'écran est formé d'une matrice de 512 lignes et 512 points par ligne. Les régistres de sortie sont conçus pour transmettre un maximum de 4000 points ce qui procure une très bonne résolution dans l'observation simultanée de 5 à 10 "bunchs".

La relative lenteur de la lecture (60 ms) permet d'envisager de nombreuses solutions électroniques, relativement simples, pour le traitement des informations (mesure de l'intensité crète, largeurs des "bunchs" à différents niveaux, phase respective, etc...).

Les solutions d'acquisition proposées actuellement vont du simple moniteur sans mémoire, aux interfaces pour CAMAC ou PDP, en passant par les moniteurs à mémoire, les moniteurs à mémoire digitale, le "Digital display controler", etc.

3) Bande passante

Le tube "scan-converter" a une bande passante supérieure à 2GHz, les oscillogrammes fournis par Tektronix montrent des oscillogrammes à 2,4 GHz.

4) Sensibilité

La sensibilité de l'acquisition est de 4^{V}/div soit 32 volts pour la déflexion totale ce qui donne une résolution de 62 mV par ligne. La sensibilité globale est bien sur fonction du moniteur et du traitement des données à la lecture.

IV. CONCLUSIONS

Le transient digitizer R7912 doit permettre la mesure des "bunchs" à 200 MHz sans modifications internes à l'appareil. Les problèmes à résoudre sont:

1) le décalage des traces pendant l'acquisition;

2) l'adaptation des sondes de mesures existantes;

3) éventuellement, la réalisation de circuits spécifiques pour le traitement des informations de sortie.

V. REFERENCES TECHNIQUES

TEKSCOPE (Nov-Dec 1973)

Storage tube with silicon target

Tektronix New Products

CAMAC APD/R7912 Controller

Pulsed laser measurement using the R7912

VI. ESTIMATION DU MATERIEL

Transient digitizer + moniteur	SF	45 000.-
Transient digitizer + mémoire digitale + moniteur	SF	57 000.-
Transient digitizer + mémoire + interface CAMAC on PDP	SF	68 000.-

REFERENCES

1) CERN/MPS/LINF 73-1, Project study for a 50 MeV linear accelerator for the CPS

2) International conference on high energy accelerators, An approach to 200 MHz bunch, measurements and limitations on longitudinal phase probes, by D.J. Warner.

3) Submitted to the 1972 Proton linear accelerator conference - Los Alamos, 10-13 october 1972, Real time measurements of proton bunch form, by L.R. Evans and D.J. Warner.

4) MPS/SR/Note 73-12, Proposal for a resistive, non-destructive UHF wide band pick-up with beams position measurement.

5) MPS/LIN/JK/ba, Comparison of sampling and real-time measurements of proton bunch form, by B. Kortegaard, H. Vilhjahnson (GSI), J. Knott and G.C. Schneider (CERN/MPS).

6) MPS/LIN/Note 75-7, Sampling measurements of proton bunch measurements hp 8410 network analyzer vs hp 8405 vector voltmeter, by W. Pirkl.

Distribution

Linac Design Committee

J. Knott

G.C. Schneider

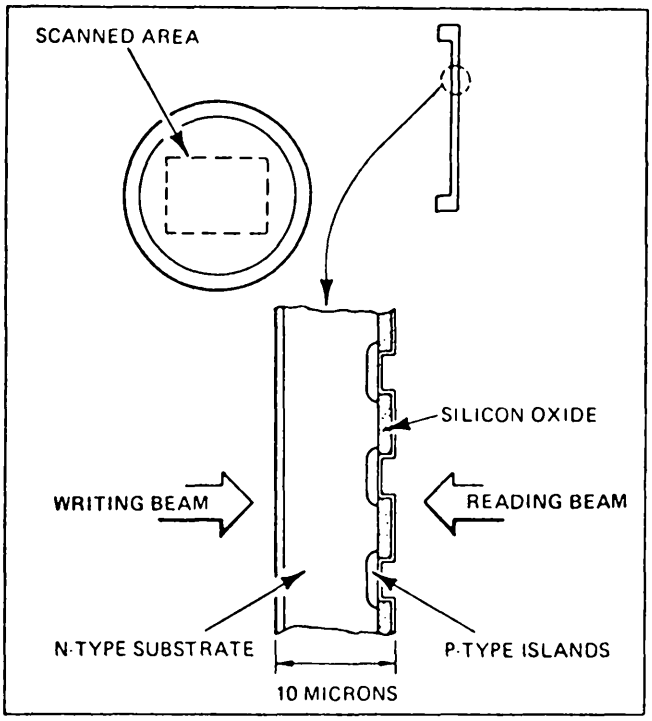
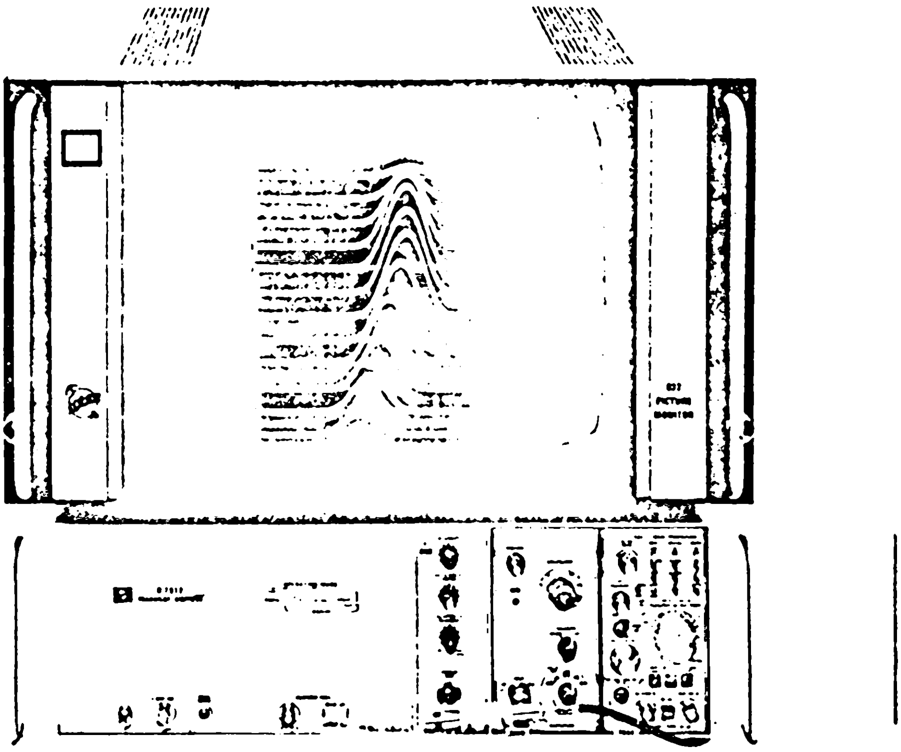
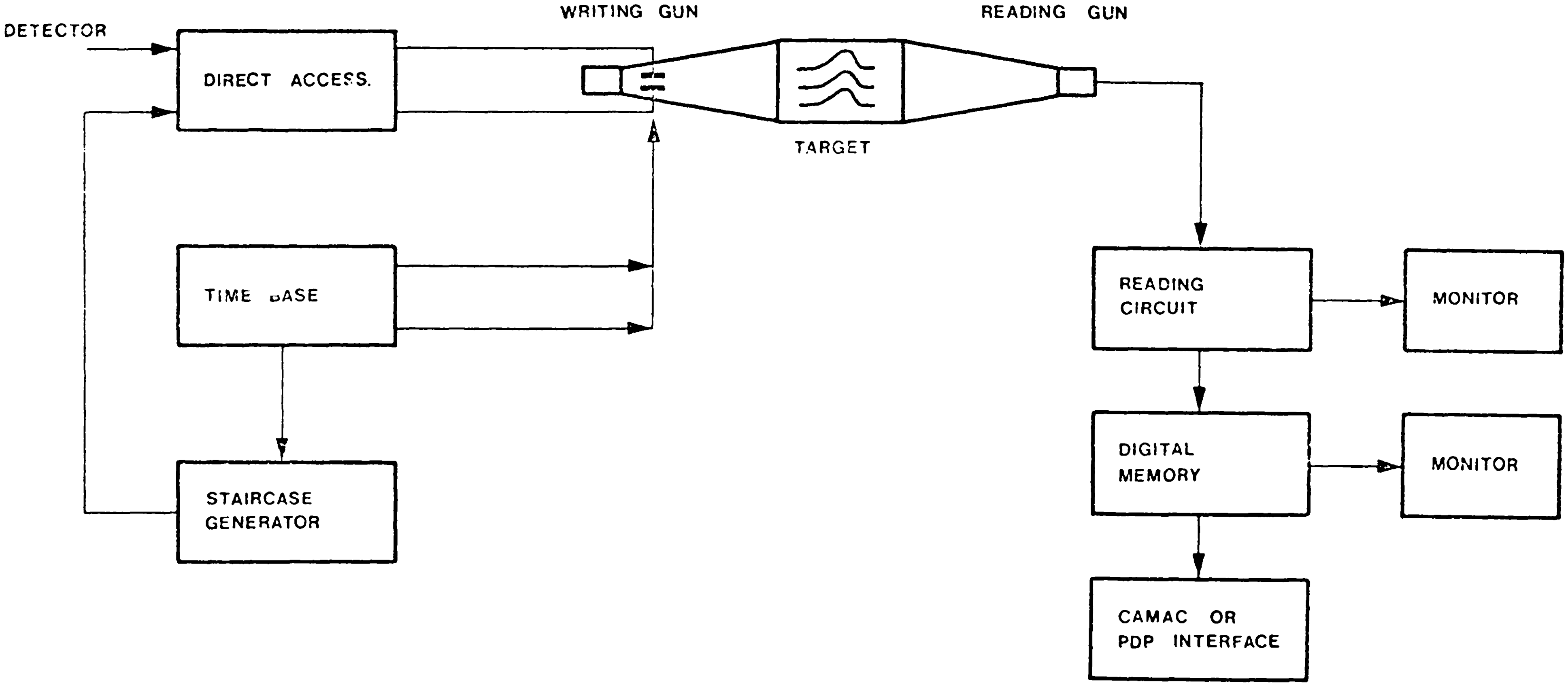


Fig. 8. Target detail.

STRUCTURE DE LA CIBLE



TRANSIENT DIGITIZER + MONITEUR



SCHEMA GENERAL

EXEMPLE D'APPLICATION DU R7912

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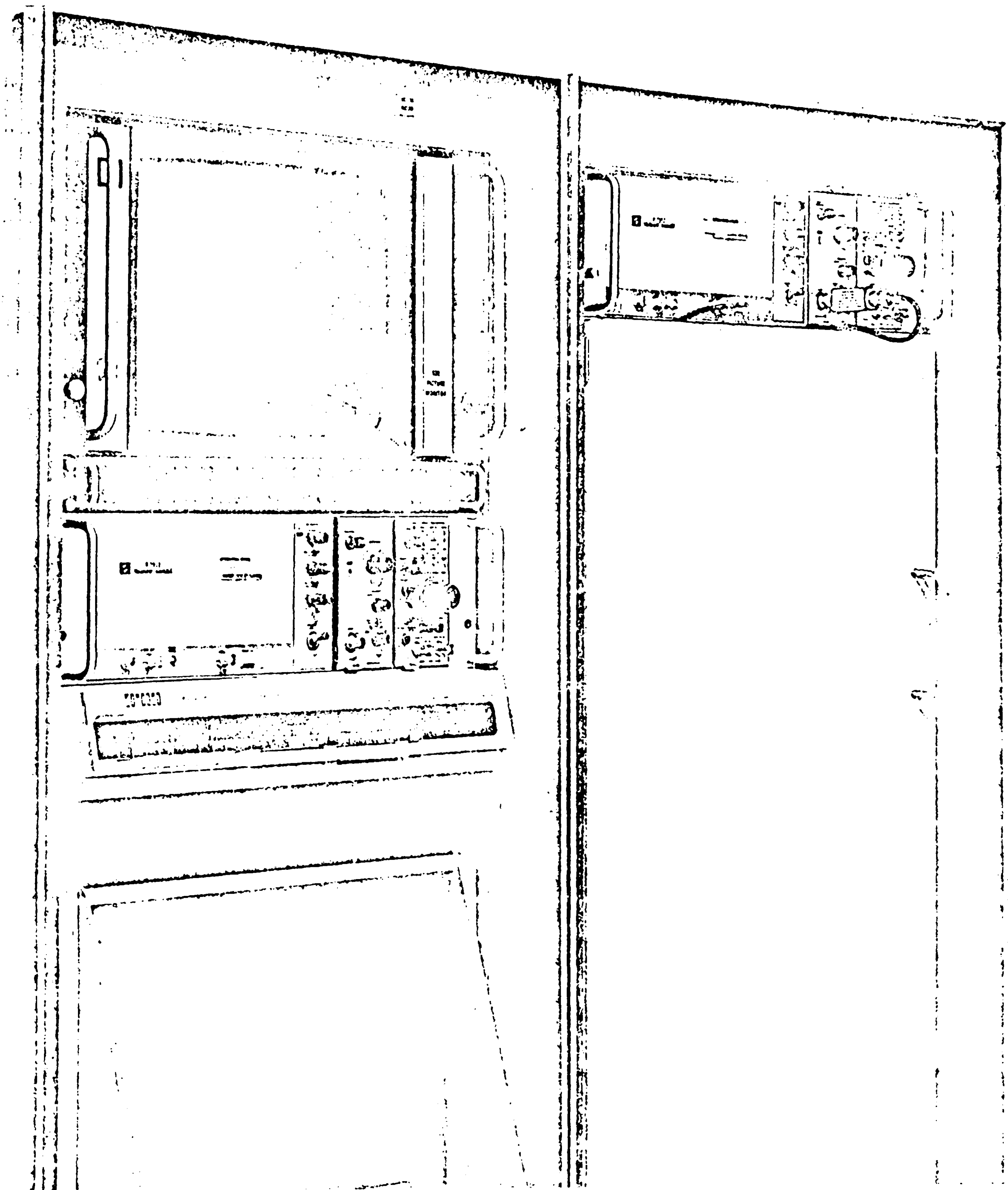
PULSED LASER MEASUREMENTS USING THE R7912 TRANSIENT DIGITIZER

R7912 Transient Digitizer Application Note 47N1.1



Pulsed Laser Measurements Using the R7912 Transient Digitizer

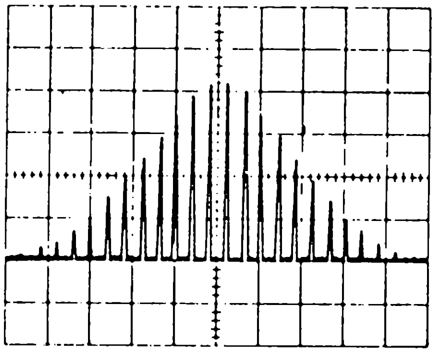
In man's search for new tools to advance his technology, many different areas have been explored. Laser technology has become one of the fastest growing fields. The laser beam can be modulated, amplified, expanded, focused, pulsed, etc. Among the many uses of lasers are: eye surgery, creation of plasma (temperatures near that of the surface of the sun), trimming resistors on an integrated circuit substrate, drilling holes through thick metal plates, and measuring distances with great accuracy. Through continuing research, new uses for lasers, in both research and practical applications, are being discovered every day. This application note pertains to the experimental portion of laser research, and to the possible roles of the R7912 Transient Digitizer in that research.

Laser Characteristics

In the detailed procedures of laser research, the two primary operations are: determining the characteristics of the pulse train, and performing alignment of the laser, which includes the cavity and the elements of the laser system. Since the signals to be analyzed are both transient and high speed in nature, detailed analysis is difficult at best, but must still be accomplished very accurately. Typically, a laser setup for research can be divided into two time frames: sub-nanoseconds and milliseconds. Sub-nanosecond pulses occur in the laser train; the gated output pulse is also in the same range. (These pulses are in the picoseconds time frame and are detected by photo diodes, which exhibit response times on the order of a few tenths of a nanosecond, so the 0.35-nanosecond risetime of the R7912 with direct access is more than adequate.) Millisecond pulses are associated with the flash lamps used to excite the laser media.

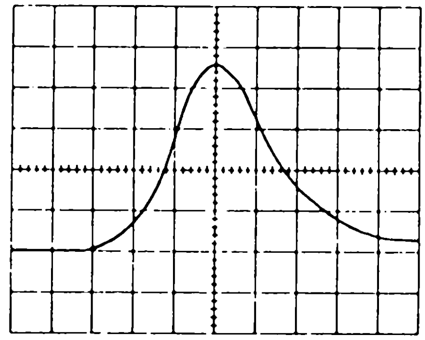
Laser/R7912 Compatibility Evaluation

To establish the applicability of the R7912 to laser activities, evaluation tests were performed with several different laser systems. In the subject evaluation tests, the R7912 was used with a 7A16 Single-Trace Amplifier, a 7B70 Time Base or a 7B92 Dual Time Base, a 601 Storage Display Unit, a Digital Display Control Unit, and a television monitor. (The television monitor was used to observe the pulse train characteristics during alignment of the laser cavity.) Three laser systems were used: one neodymium-doped glass, and two neodymium-doped YAG (yttrium/aluminum/garnet) crystal. The cavity length for all three lasers resulted in a pulse separation of approximately eight nanoseconds; the repetition rate varied from one shot every four minutes for the glass laser to three shots per second for one of the YAG lasers. Two types of laser light detectors were used (with no noticeable degrading of the pulses): a Hadron Model TRG-105C and a Hewlett-Packard Model HP 4220 photo diode. The latter detector was mounted in a housing designed by physicists at the Los Alamos Scientific Laboratory. Mounted in this housing, the inexpensive HP 4220 detector exhibited response characteristics equivalent to the more costly TRG-105C; that is, on the order of a few tenths of a nanosecond. Typical observed signals are shown in Figures 1 and 2.



20 NS/DIV

Figure 1. *Laser Pulse Train*



0.5 NS/DIV

Figure 2. *Gated Output Pulse*

The YAG laser with the repetition rate of three shots per second was tuned using the television monitor to follow the change in the waveform. (The persistence of the television screen was appropriate to permit the eye to follow the change in quality and amplitude of the pulse train.) Also observed using this technique was the absence of a gated output pulse. This is shown in Figure 3. The other two lasers, operating at much slower repetition rates, were tuned using the storage display unit and the Digital Display Controller. Repeated retracing produced a good indication of what happens to the laser pulse train with respect to quality and amplitude. Some pulse trains exhibited multiple modes separated by approximately one nanosecond. Also, there is a possibility that additional modes closer in time were present, but no attempt was made to resolve that question. All resultant data were computer compatible, however, it was not deemed necessary to the evaluation tests to process the data.

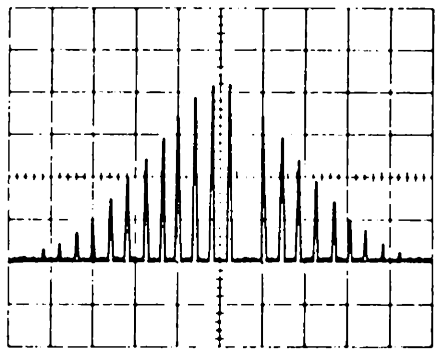


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Figure 3. *Absence of the Gated Output Pulse*

From the foregoing discussion and illustrations, recommendations may be made concerning the configuration of a laser measurement system. A typical recommended setup is shown in Figure 4. As shown in the illustration, the laser oscillator and amplifier outputs may be monitored by an R7912 with a photo detector at each stage. A pellicle, which removes only about eight percent of the beam power, is used for this purpose. Also, the switch-out device (Pockel cell) output may be monitored in the same manner.

In addition to the operational and technical benefits, use of the R7912 can also effect certain economies. For example, under some conditions, it is possible to multiplex the signals from the light pumps (flash lamps) into one R7912. (Note that these signals change at millisecond rates.) With a suitable multiplexer unit, up to three light pump signals may be processed by one R7912. This high speed capability of the R7912, when added to the fact that consumable supplies such as film need not be used, reduces the long-term cost of system operation to the point at which there is little, if any, cost advantage in the use of the conventional oscilloscope/camera system.

Laser Plasma Research

In generation of laser plasma, some key questions concern the characteristics of the plasma. These include:

- What is its temperature?
- What are the atomic species present?
- What are their energies?

A typical experimentation system to answer these questions, and others, is shown in Figure 5.

Many of the present techniques depend on atomic measurements. The Faraday cup, for example, will allow measurement of the charge of particles entering the detection region. The output signal appears as peaks separated in time and corresponds to different charges and species (a heavy atom will move more slowly than a light atom). Such signals are in the microseconds time frame. Another detector that operates on atomic level is the cylindrical analyzer, which divides the species according to charge and mass; i.e., E/Z. As with the Faraday cup, the output signal consists of peaks separated in time and is in the microseconds time frame.

Details of construction of the Faraday cup and cylindrical analyzer and the equations that describe the output signals of those devices may be found in many textbooks, articles, trade journals, etc. Two excellent articles pertaining to the cylindrical analyzer are: Penetration of Low-Energy Protons through Thin Films, by G.L. Cano, in the Journal of Applied Physics, Vol. 43 No. 4, page 1504, April 1972; and Electrostatic Analyzer for Selection of Homogeneous Ion Beams, by R.E. Warren et al., in the Review of Scientific Instruments, Vol. 18, page 559, 1947.

One of the major problems associated with plasma experimentation is determining when the plasma pulse actually starts in relation to the acquired data. External triggering is one method. A more desirable method however, is to supply a fiducial pulse on the same signal line as the true

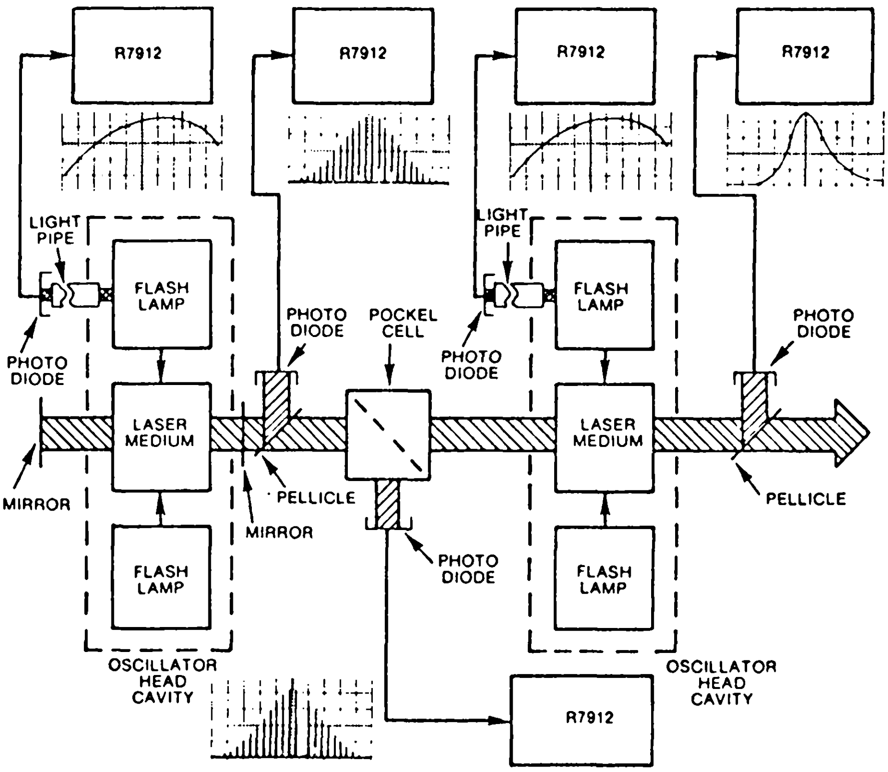

Figure 4. *Typical Recommended System Configuration*

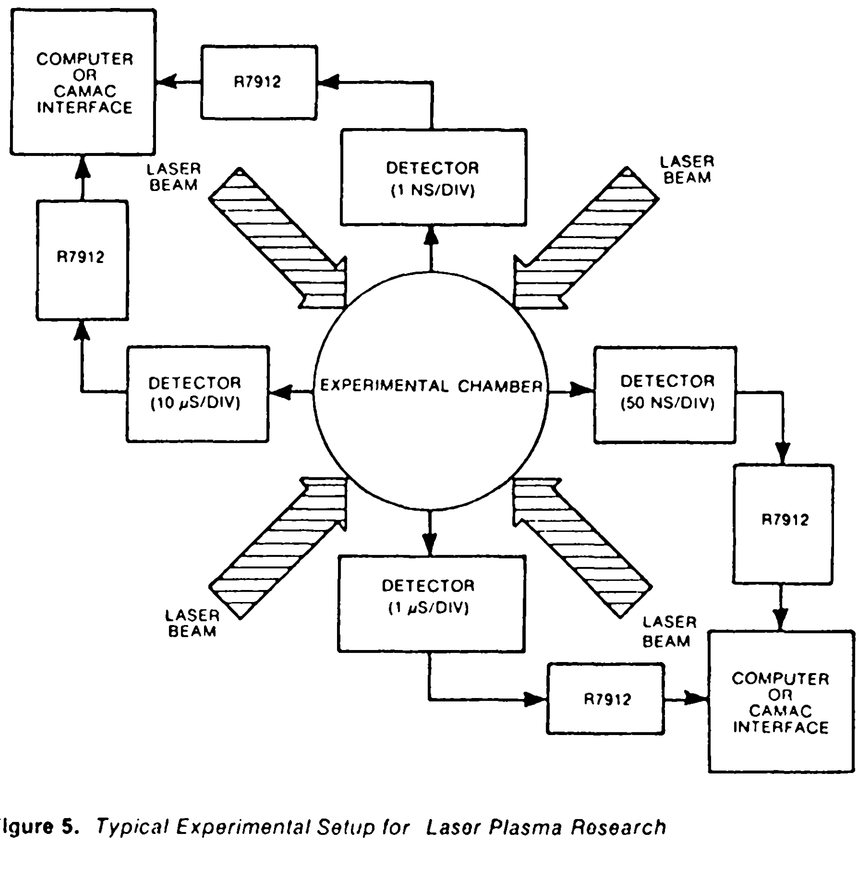

Figure 5. *Typical Experimental Setup for Laser Plasma Research*

signal or to the same signal acquisition unit for combining (for example, a 7A24 Dual Trace Amplifier used in the signal addition mode). The fiducial pulse could be the plasma x-ray pulse, which moves at the speed of light — much faster than that of particles. This method is relatively complex in its execution, but it is a very effective solution to the problem.

Another problem area concerns the measurements of plasma temperatures in determining energy levels. These temperatures may be measured using x-ray detectors set in an x-ray spectrometer geometry (such signals are in the nanoseconds time frame). Using different filters in front of solid-state detectors allows for selection of slices of the nperature curve for analysis. This hnique is described in the article: Plasma X-Ray Diagnostics, by J. Cuderman et al., in the Bulletin of the American Physical Society, October 1973, page 1342; and was verified for compatibility with R7912 operations in private communication with J. Cuderman. In this measurement, R7912's would be used to digitize the information. A computer could then be used to calculate the temperature. The speed of the R7912 provides that this could be accomplished between laser shots. Thus, the experimenter would have plasma temperature data quickly to determine if the shot accomplished the objectives and what the parameters should be for the next shot.

Yet another important area of measurement interest is scattered laser light. Measurement of this phenomenon indicates to the physicist how effectively the laser energy is being absorbed into the target material. The overall importance of scattered light is sufficient that, in many industrial fields, experiments and analyses could very easily become extensive research programs in the study of materials.

The R7912 compatibility with computers adds to the ease with which measurements of signals from laser plasma and laser fusion experiments may be made and analyzed. An important consideration is that data may be assessed to determine its quality before it is entered into a computer for storage or analysis. After analysis, which can occur very quickly, the experimenter can have at hand a complete set of data on a laser shot before proceeding to the next phase or experiment.

Since target data from Faraday cups, cylindrical analyzers, and x-ray solid-state detectors are well within its capabilities, the R7912 provides an excellent method for recording and storing these data. The most significant feature of the R7912 however, is its unprecedented speed in performing these operations. Investigations into current laser plasma experiments indicate that R7912 type recording is appropriate to all measurement techniques, except perhaps the Thomson parabola.

Summary

Results of actual use of the R7912 in daily operation of laser systems indicate conclusively that the R7912 is a very effective time saving device. With it, data can be processed and available for parameter adjustments immediately instead of the several days, or weeks, or months required in using the old methods of essentially hand digitizing oscilloscope display photographs for computer analysis.

The ideas and techniques discussed in this note present the R7912 as a possible solution to some of the more important problems of laser operation. These ideas and techniques apply equally well to the large number of other disciplines wherein the digitizing of sub-nanosecond waveforms is required.

Once captured by the R7912, signals can be processed by the WDI TEK BASIC software. Based on the interactive, easy-to-learn Dartmouth BASIC software, WDI TEK BASIC incorporates very efficient waveform analysis functions. Callable commands provide for waveform parameter measurements, multiplication, division, convolution, correlation, and the more complex fast Fourier transform and its inverse.

For more information, contact your local Tektronix Digital Applications Engineer or write: Tektronix, Inc., P.O. Box 500A, Beaverton, OR 97005.

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