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TITLE AN OVERVIEW OF THE LONG PULSE EXPERIMENT

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AN OVERVIEW OF THE LONG PULSE EXPERIMENT

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The application of single pulse optical lasers to strategic defense has been under study by Los Alamos and other laboratories for several years. Various wavelengths from 0.25 μm to 10.6 μm have been experimentally studied to provide a database for laser-target interactions, predominantly for laser pulse lengths $\tau_L < 1\ \mu s$. The fluence range 10^2-10^5 J/cm^2 has been explored for a number of materials ranging from aluminum to plastics and composites. Measurements of the impulse coupling coefficient (total momentum imparted as a result of all laser-target interaction processes / total incident energy) as a function of fluence are fairly complete for the short pulse, low energy, essentially one dimensional regime, with fluences up to about 10^3 J/cm^2, accessible in the laboratory.

Simple 1D models of laser generated impulse for pulse lengths up to about 1 ms have shown a trend to higher coupling efficiency for fixed fluence at longer pulse lengths. This would lead to more efficient use of the available laser energy in a real defensive system. Such a trend would drive SDI laser system design toward long pulse lengths to minimize the required energy in the beam, but needs verification before becoming a driving design issue. Experimental verification of such a trend requires a focal spot size of linear dimension larger than the intra-pulse laser induced plasma expansion distance, in order that the laser-plasma interaction retain the 1D characteristics expected for a real defensive engagement. For long pulse lengths, this cannot be achieved with the energies available from laboratory lasers, while simultaneously maintaining the fluence and flux levels of interest. The major thrust of the experimental laser-effects physics program has therefore become the testing and validation of analytic models and numerical simulation tools such as LASNEX, in regimes as close to those envisioned as possible, so that the models may be used to predict the interaction in the real situation with adequate confidence. An experiment conducted at KMS Fusion, Inc. during the period 2-26 September 1986, using the 1.054 μm wavelength Chroma laser, was the first experimental study at very long pulse lengths and constitutes the first phase of this testing process. The available energy (<2.5 kJ) and fluence ($<10^5$ J/cm^2) in this experiment, which utilized pulse lengths of 0.5, 8, and 128 μs, implied a dimensionality ranging from 1D to highly 2D. Comparison with calculational results therefore requires fully 2D simulations. Such simulations are currently being undertaken at several laboratories.

The experiment reported here was designed to enable a detailed comparison between the calculational tools and measurable quantities such as the pulse length dependence of impulse generation efficiency. In particular, targets were designed to distinguish between impulse generated directly by the laser-solid interaction, and that component due to secondary coupling processes such as lateral reradiation from the hot plasma layer in front of the target, and pressure from plasma expansion along the target surface. We measured front surface pressure as a function of time (and correlated it to the laser power history), and measured the net impulse within the focal spot separately from that outside the laser spot. The impulse coupling increased at fixed fluence for longer pulse lengths as predicted, but the target surface damage suggests that the experiment was dominated by 2D effects that overwhelm the 1D coupling enhancement of the simple model. Separate impulse measurements, combined with the appearance of the target after a shot, suggest that at large spot sizes and low fluence levels, most of the laser-target interaction is restricted to the area of the initial laser focus. At the highest fluence levels (and smallest spot sizes), secondary processes combine to couple the incident energy to a region far larger than the initial spot size, with net impulse generation outside the spot comparable to that in the initial focal region.

A simple 1D model of the interaction would predict that for the longer pulse lengths, the absorption layer would be further from the target surface due to longer expansion times, whereas 2D calculations which allow radial expansion show stabilization of the absorption layer near the target surface. Neither time resolved nor still photography show any increase in the axial extent of the visible plume that might be associated with a 1D increase in standoff distance. What the photographic records and axially resolved luminosity measurements reveal is that for longer laser pulses at fixed fluence, the axial extent of the luminous region decreases, possibly due to differences in plasma temperature caused by the significantly lower flux. The linear extent along the target surface is comparable for all pulse lengths for a given spot size. In the 128 μs case early in the laser pulse (5 μs) the radial extent of the cloud at all axial locations is much larger than the focal spot for the smaller spot sizes. In contrast to this, the behavior away from the target surface throughout the duration of the 0.5 μs laser pulses suggests that some pinching of the blowoff plasma may be occurring, perhaps connected with self-induced magnetic fields due to the higher intensity in these shots.

The results are encouraging from the laser coupling point of view, but more information is required before the physics can be completely understood. In particular, if another sequence of long pulse interaction studies were to be conducted, some technique to distinguish between secondary target interactions due to reradiation and those due to plasma pressure needs to be found. This might involve application of magnetic fields, radial resolution of both energy and particle deposition on the non-illuminated part of the target, and other as yet unidentified techniques. The apparent pinching behavior in the plume seen for the 0.5 μs laser pulses needs further study for the longer pulse lengths at early times using the same fast framing photography. Finally, quantitative measurement of the density profile and time history in the plume using interferometric techniques (holographic and time resolved line-of-sight) needs to be done in order to compare experimentally produced plasmas to those predicted by the fully 2D LASNEX simulations and other code results. At the present time, simulations are not sufficiently complete to indicate which of the several available codes predict most accurately the experimental observations, or why. Total impulse predictions from all codes are, however, within a factor of two of the observed impulse in the experiment.

OVERVIEW OF LPX-I

R. G. WATT

LOS ALAMOS NATIONAL LABORATORY

PRESENTED AT THE LTH2/3 QUARTERLY

REVIEW, 12/10/86

THE LONG PULSE PHASE I EXPERIMENT

SEPT 2-26 1986   KMS FUSION

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KMS OPERATIONS

K.MONCUR, R.MASTERS, R.JOHNSON, M.BYERS, B.LAWRENCE

EXPERIMENTAL GOALS

- MEASURE IMPULSE COUPLING EFFICIENCY AS A FUNCTION OF PULSE LENGTH, FLUENCE, AND FLUX AT 1.054 U
- MEASURE MASS LOSS, EXPANSION VELOCITY, AND PLUME CHARACTERISTICS
- MEASURE P VS. T FOR SEVERAL FLUENCE LEVELS
- MEASUREMENTS ON 1100 AL WITH SELECTED SHOTS ON GRAFOIL AND AN ORGANIC MATERIAL

PARAMETER RANGES

ENERGY .5-2 KJ

PULSE LENGTH .5, 8, 128 US

SPOT SIZE 2-32 MM

FLUENCE 6.4×10^{4} - 6.2×10^{1} J/CM^2

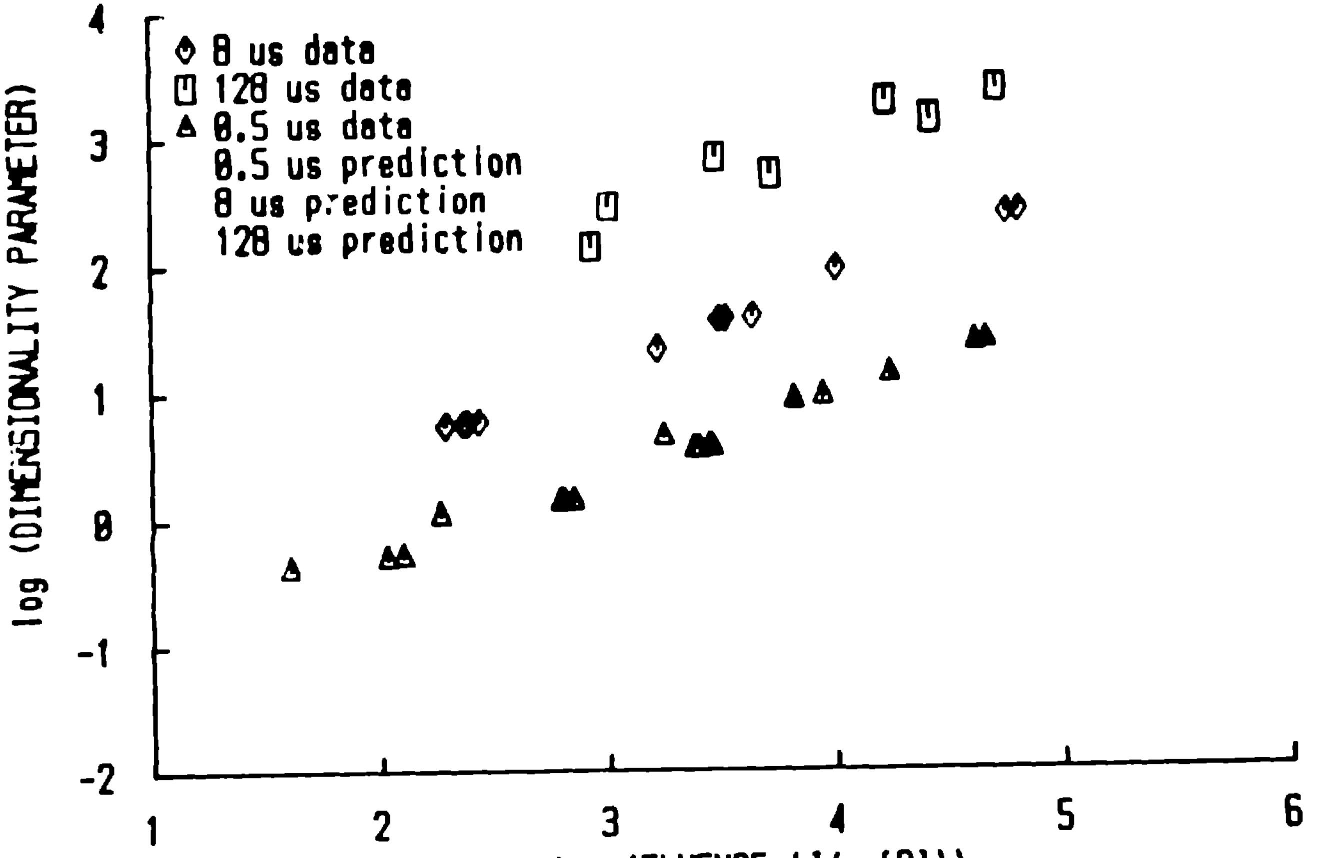
FLUX 1.3×10^{11} -4.9×10^{5} W/CM^2

INCIDENCE ANGLE 0, 60°

PRESSURE 0-760 mtorr

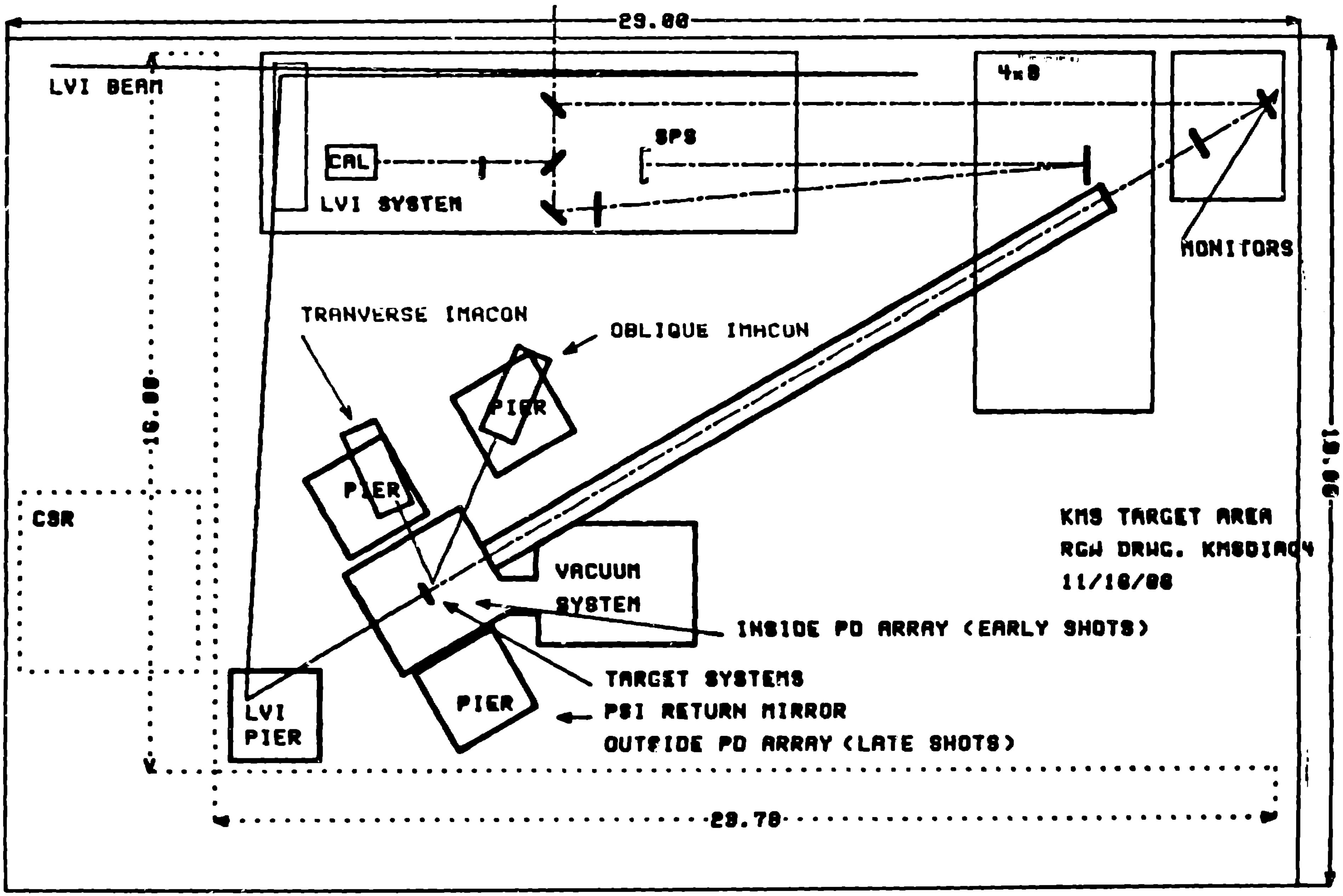
The dimensionality parameter (tau-hat) is given by Tlaser*V/Rbeam

V comes from a fit to the expansion velocities given in the code comparison in the proceedings of the SUBWUG GP meeting, 1986, by R. S. Dingus, et. al.



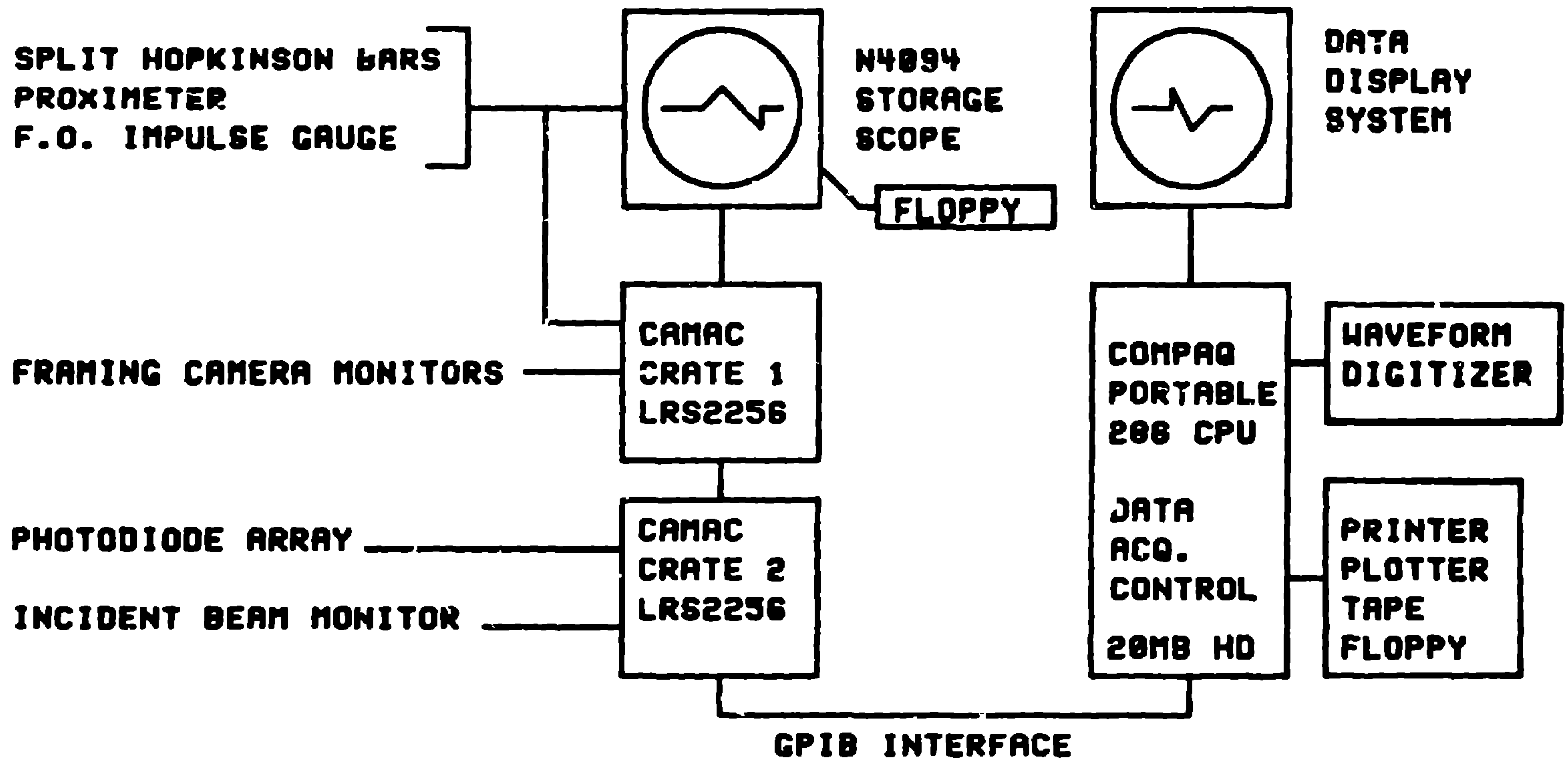
LPX I database, including predictions,11/15/86

Al at vacuum, 0 degrees,lvi and shb included



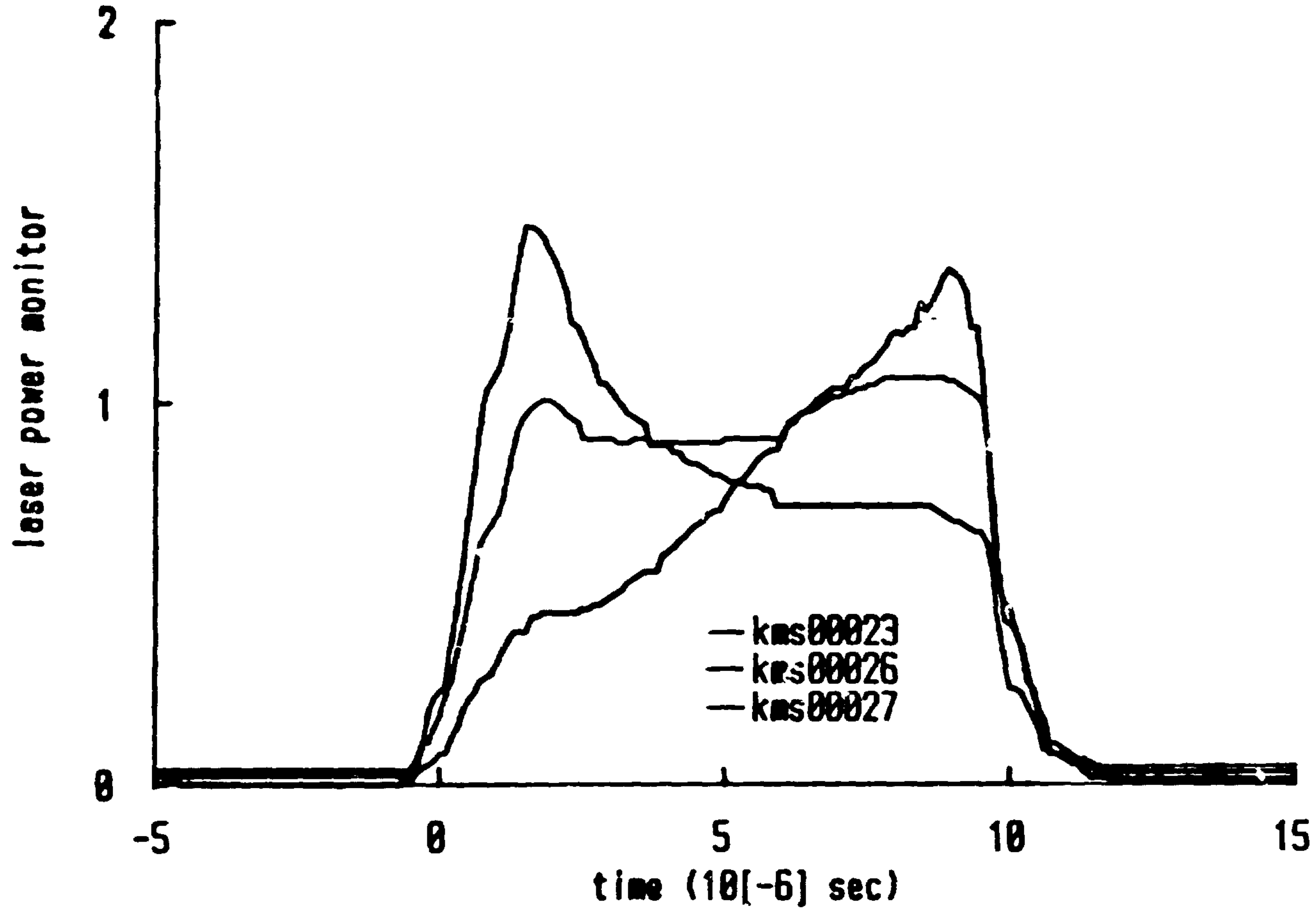
LPX I EXPERIMENTAL LAYOUT

_PX I DATA ACQUISITION SYSTEM



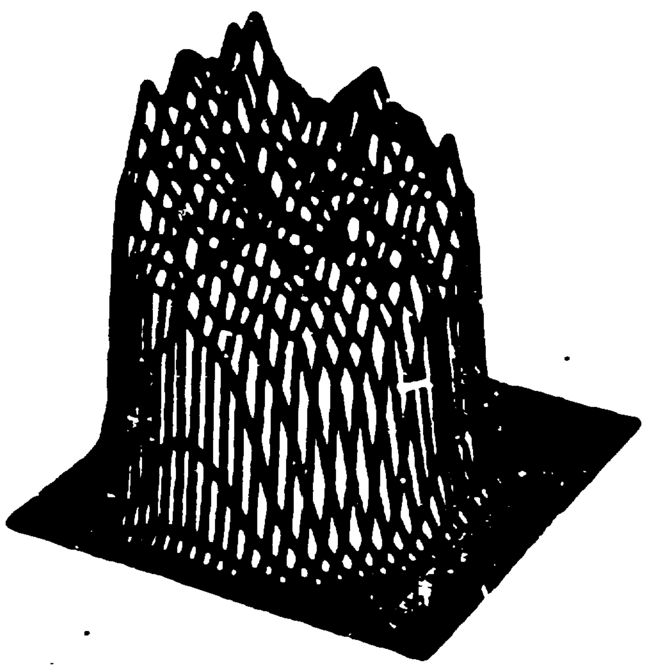
SHOT LOG AND SYNOPSIS RESIDES IN A REFLEX DATABASE
SHOT READOUT IS SOFTWARE LIMITED AT PRESENT
TO ABOUT 3-4 MIN FOR 14 ADC + 4 SCOPE TRACES

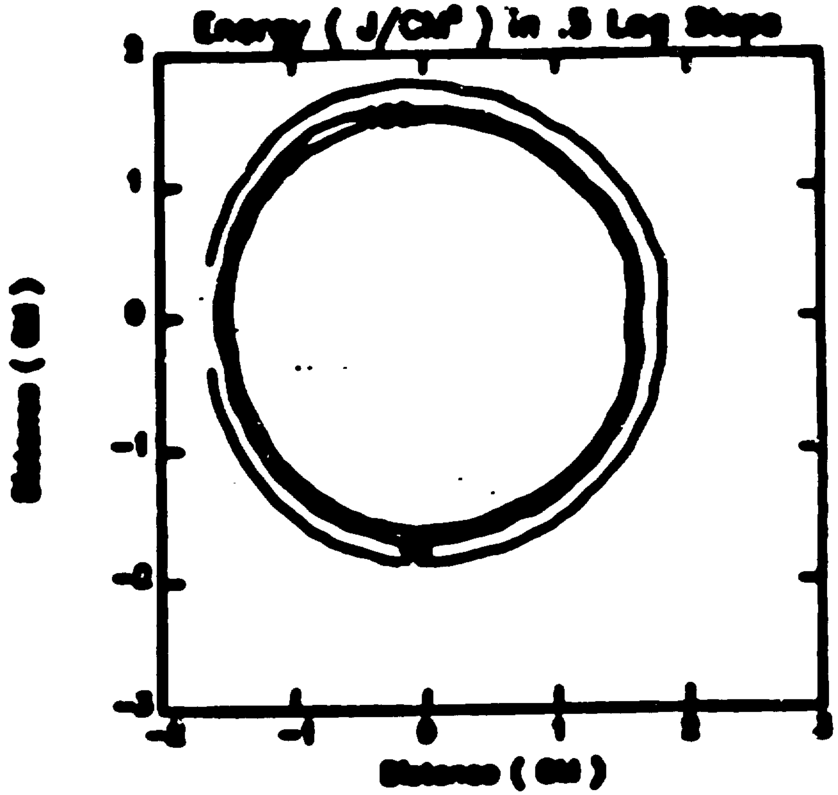
OVERLAY OF SEVERAL 8us LASER PULSES



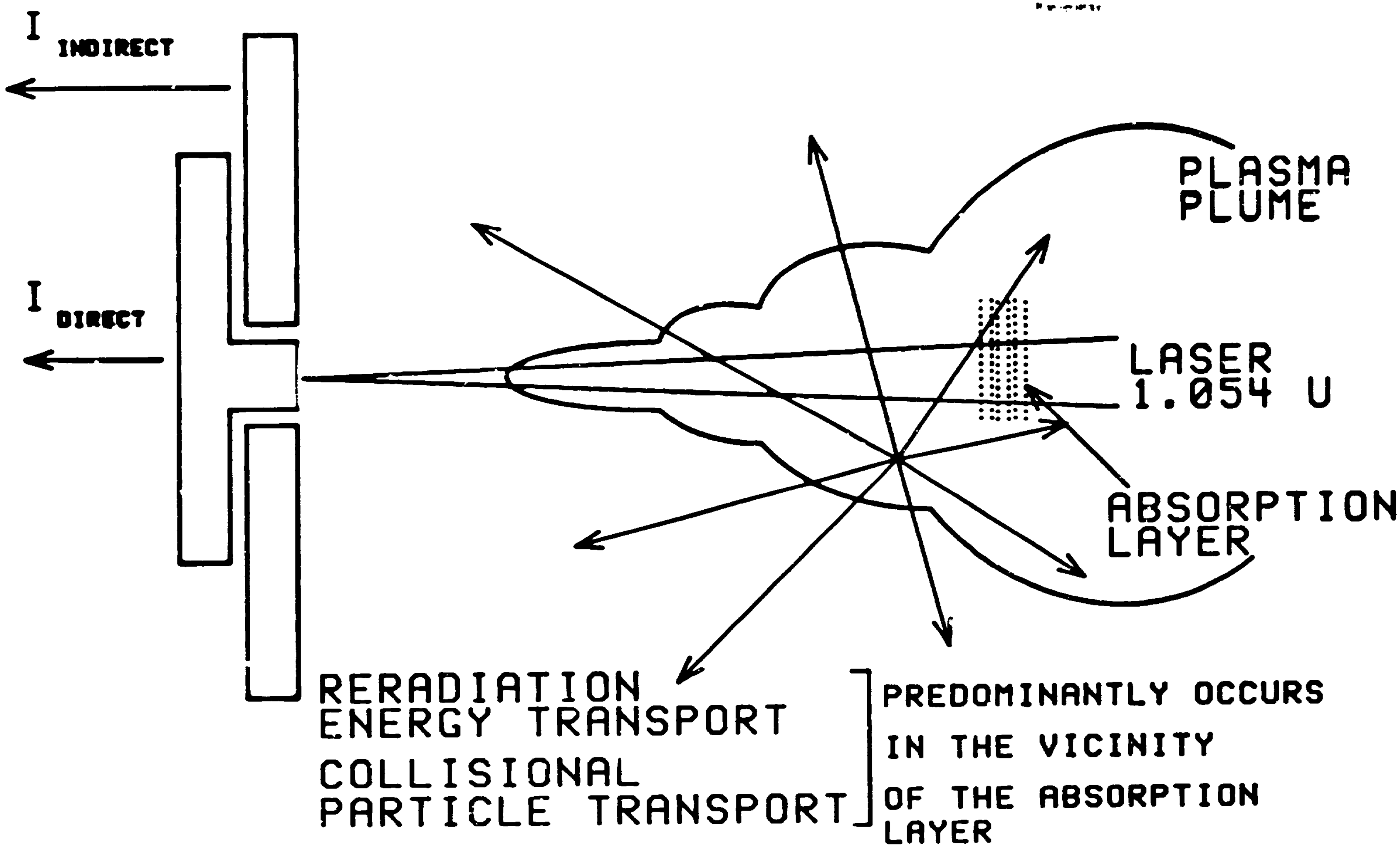
NEAR Field Analysis

SHOT: 8134 **SHOT ENERGY: 1566.00J**

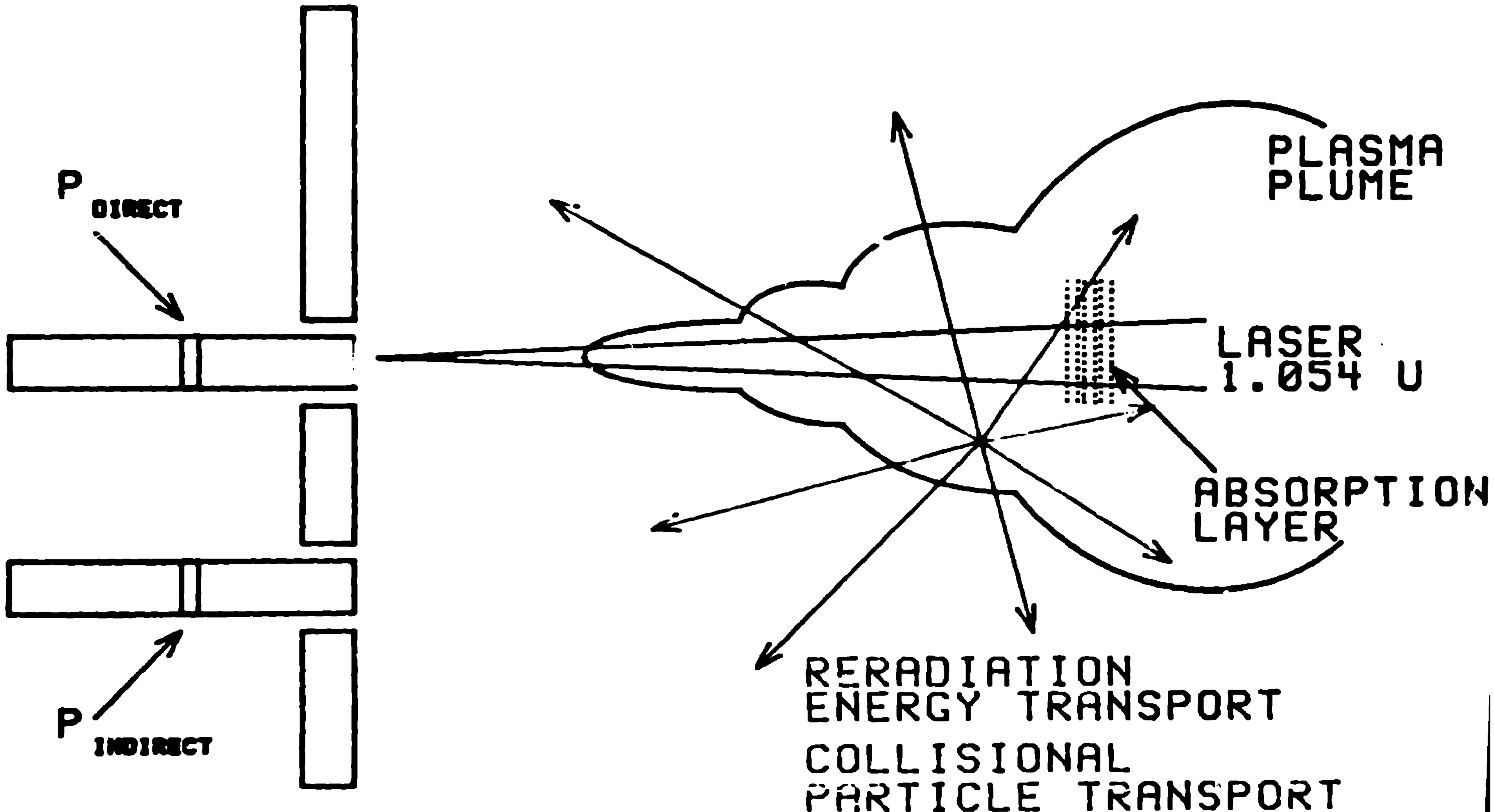




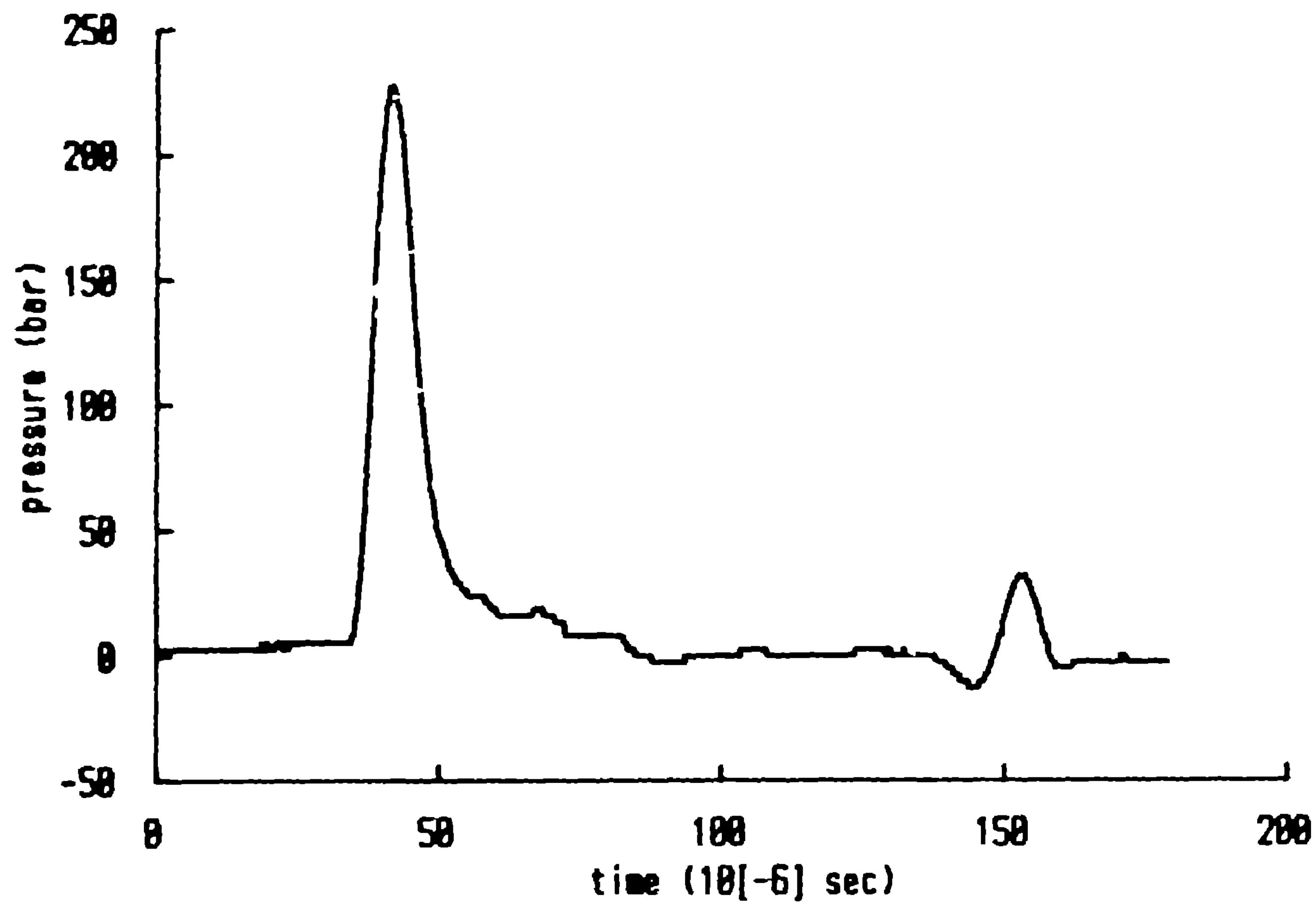
8μs τ_p, 32 mm Spot


I INDIRECT
I DIRECT
PLASMA PLUME
LASER 1.054 U
ABSORPTION LAYER
RERADIATION ENERGY TRANSPORT
COLLISIONAL PARTICLE TRANSPORT
PREDOMINANTLY OCCURS IN THE VICINITY OF THE ABSORPTION LAYER

PRESSURE VS. TIME (TWIN SHB)

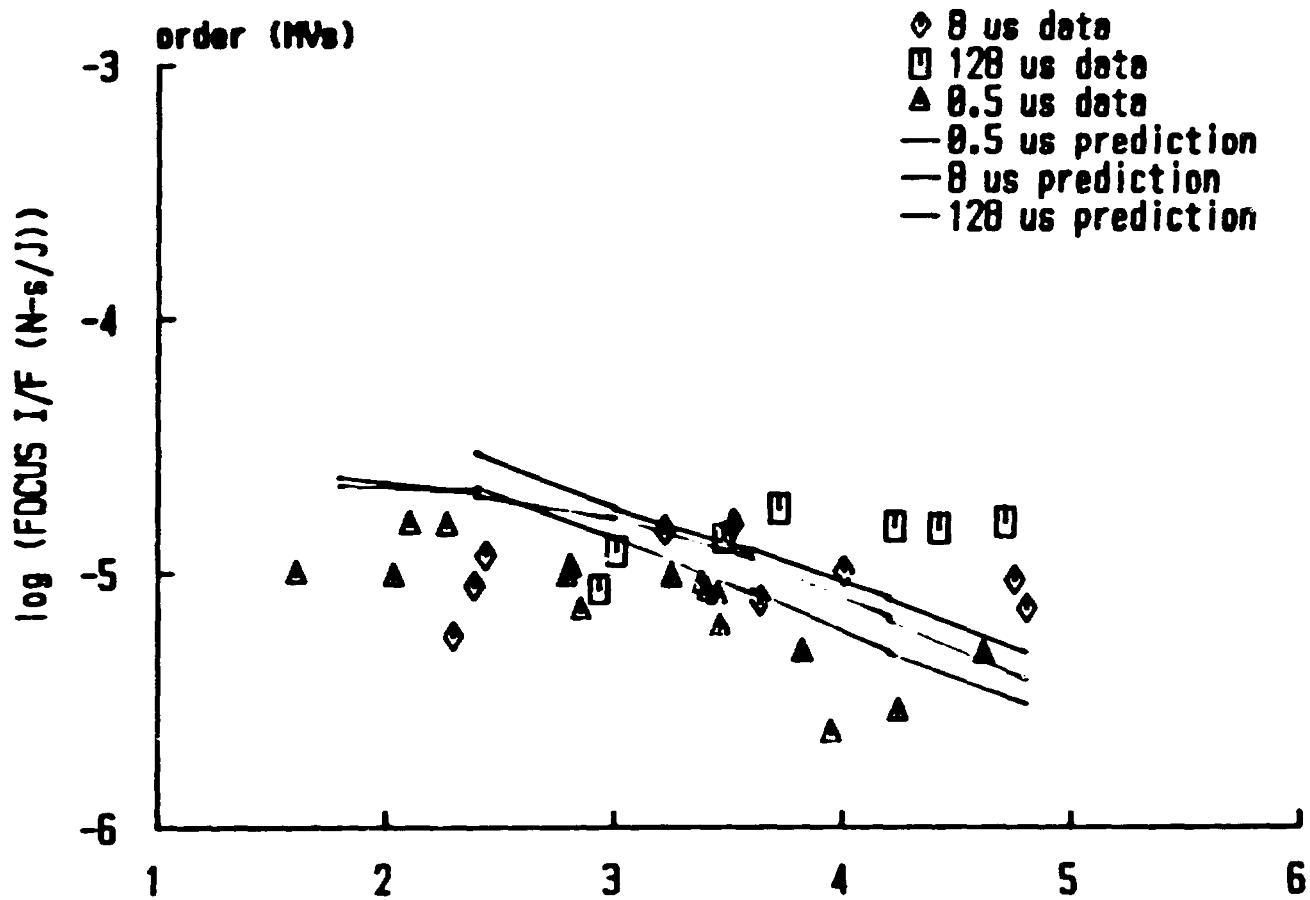


SPLIT HOPKINSON BAR PRESSURE PULSE, 4 mm SPOT, 1.1 kJ, AL

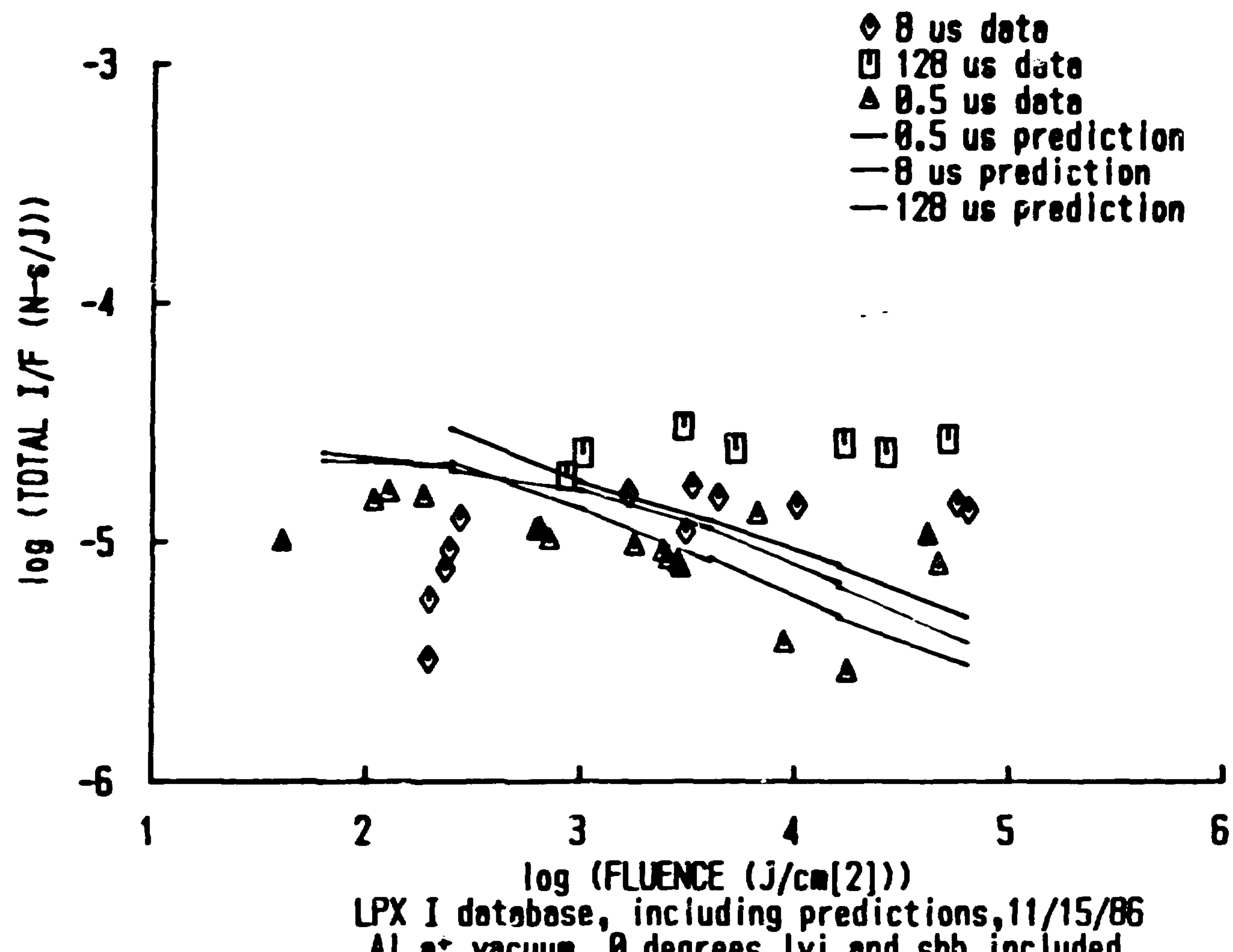


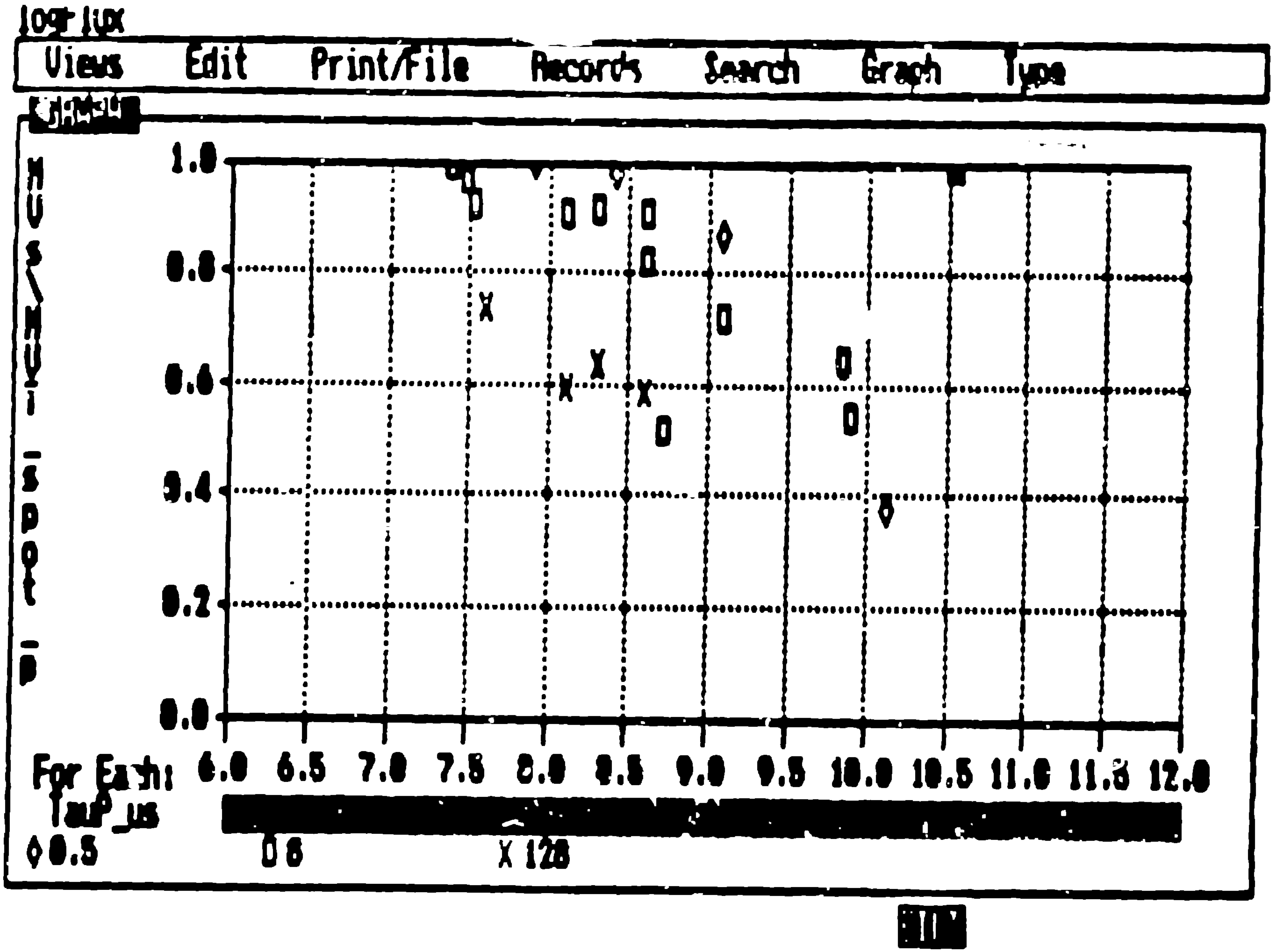
KMS00006

Part of the total impulse imparted at higher fluences is due to secondary transport to the area outside of the laser focal region. At the highest fluences the impulse delivered to the annulus is of order (MVs)

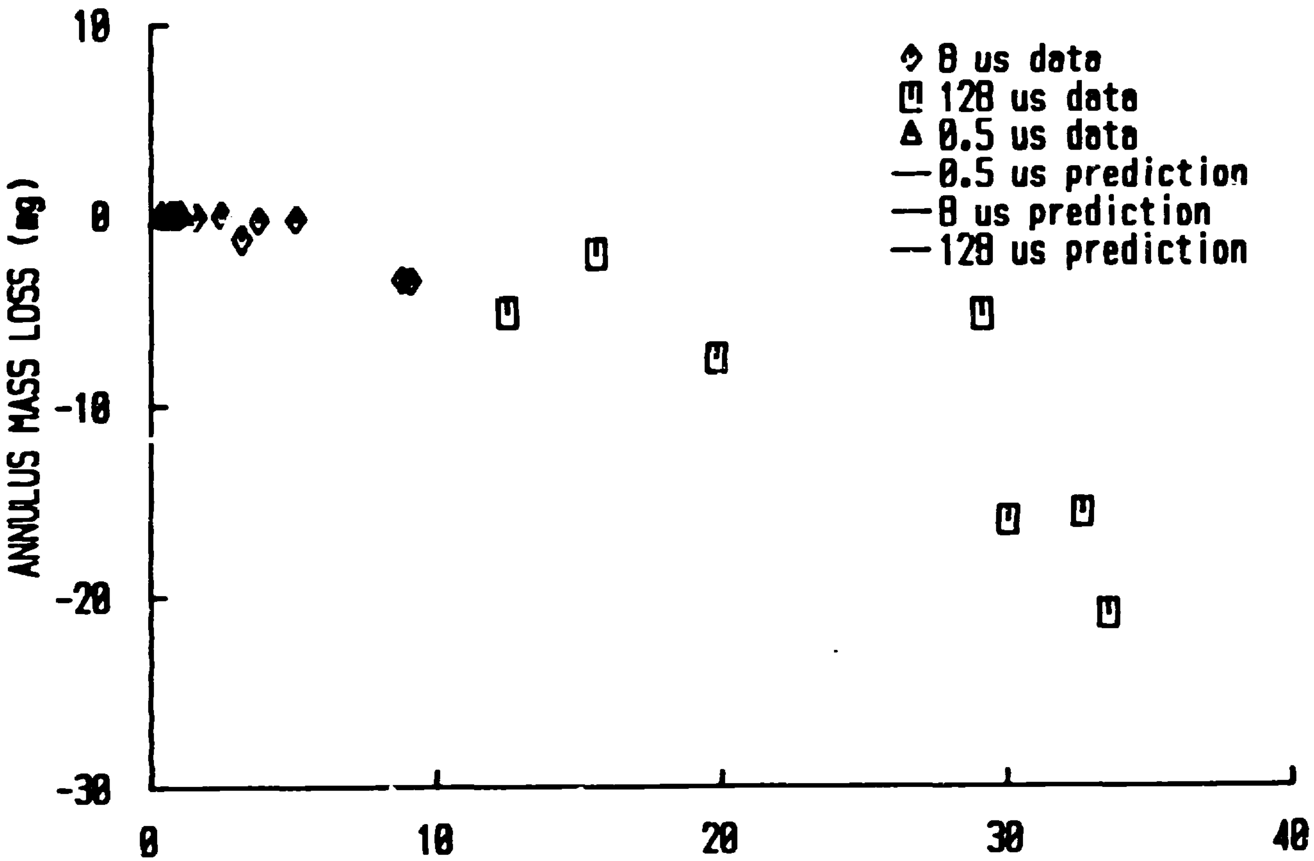


LPX I database, including predictions, 11/15/86
Al at vacuum, 0 degrees, lvi and shb included

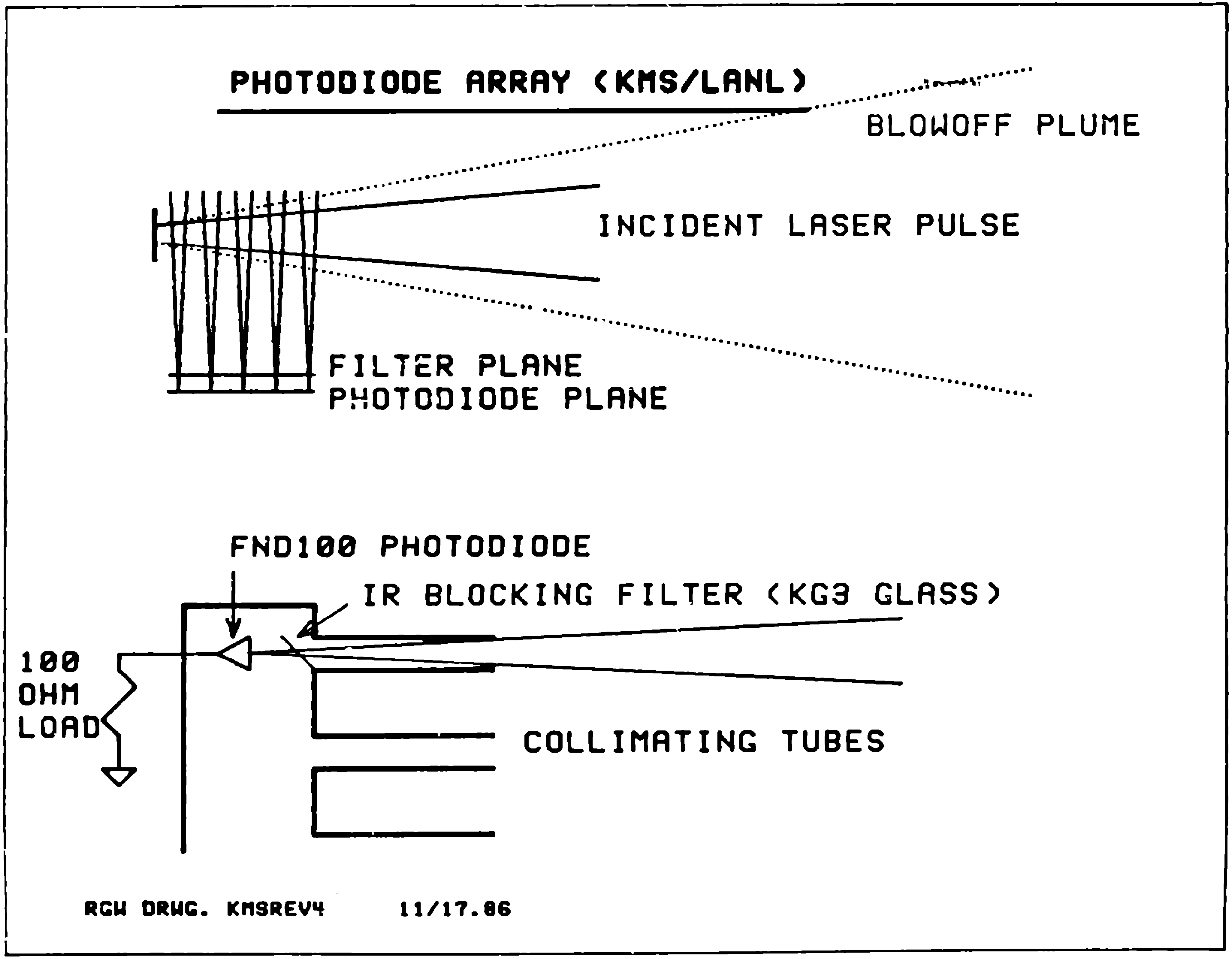

◇ 8 us data
□ 128 us data
△ 0.5 us data
—0.5 us prediction
—8 us prediction
—128 us prediction
log (TOTAL I/F (N-s/J))
-3
-4
-5
-6
1
2
3
4
5
6
log (FLUENCE (J/cm[2]))
LPX I database, including predictions,11/15/86
Al at vacuum, 0 degrees,lvi and shb included


Views
Edit
Print/File
Records
Search
Graph
Type
1.0
0.8
0.6
0.4
0.2
0.0
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
12.0
For Each:
TauP_us
◊ 0.5
□ 6
X 128

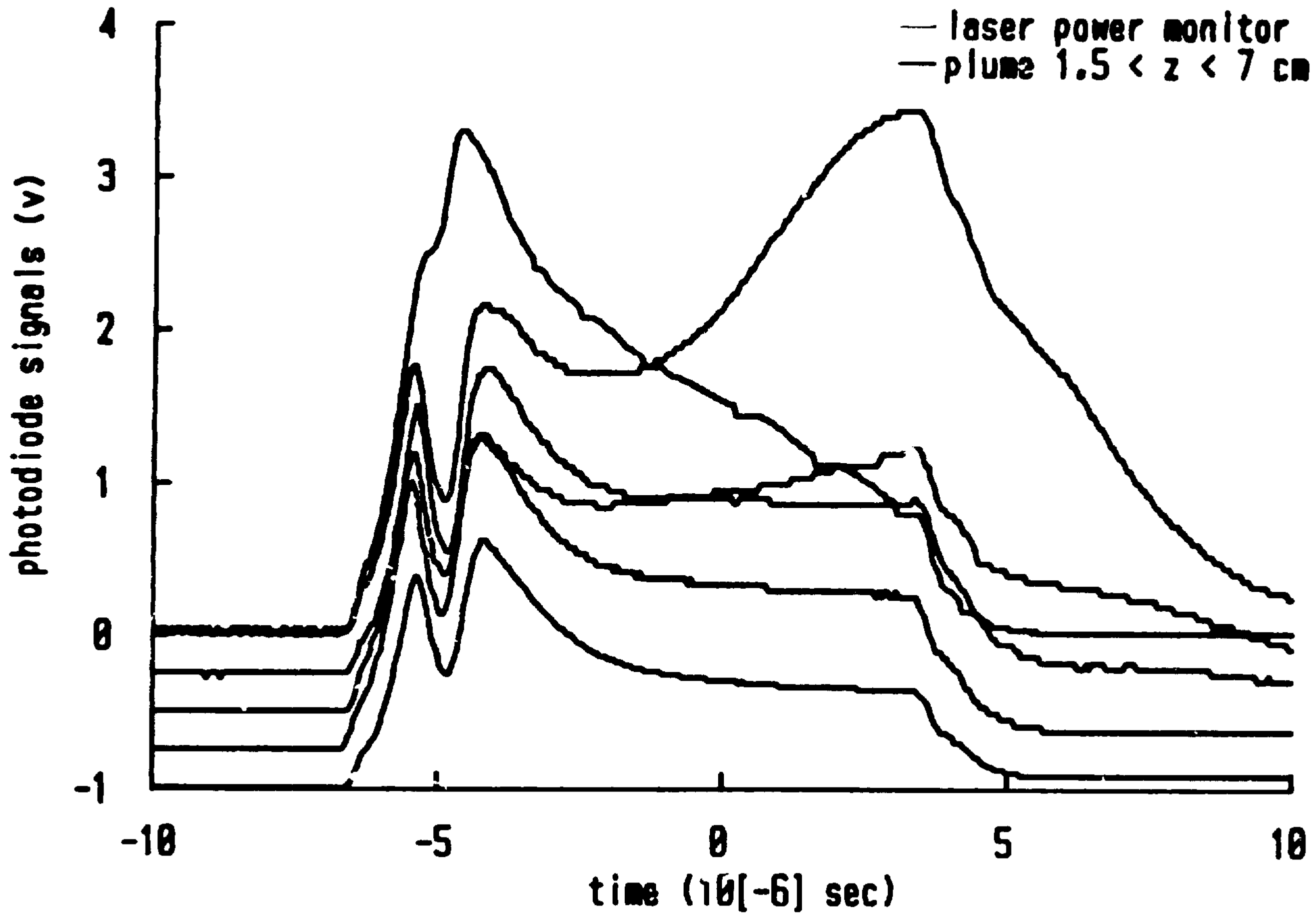
As much as 1/2 the mass lost from the spot can show up on the annulus, but very little impulse seems to be derived from it



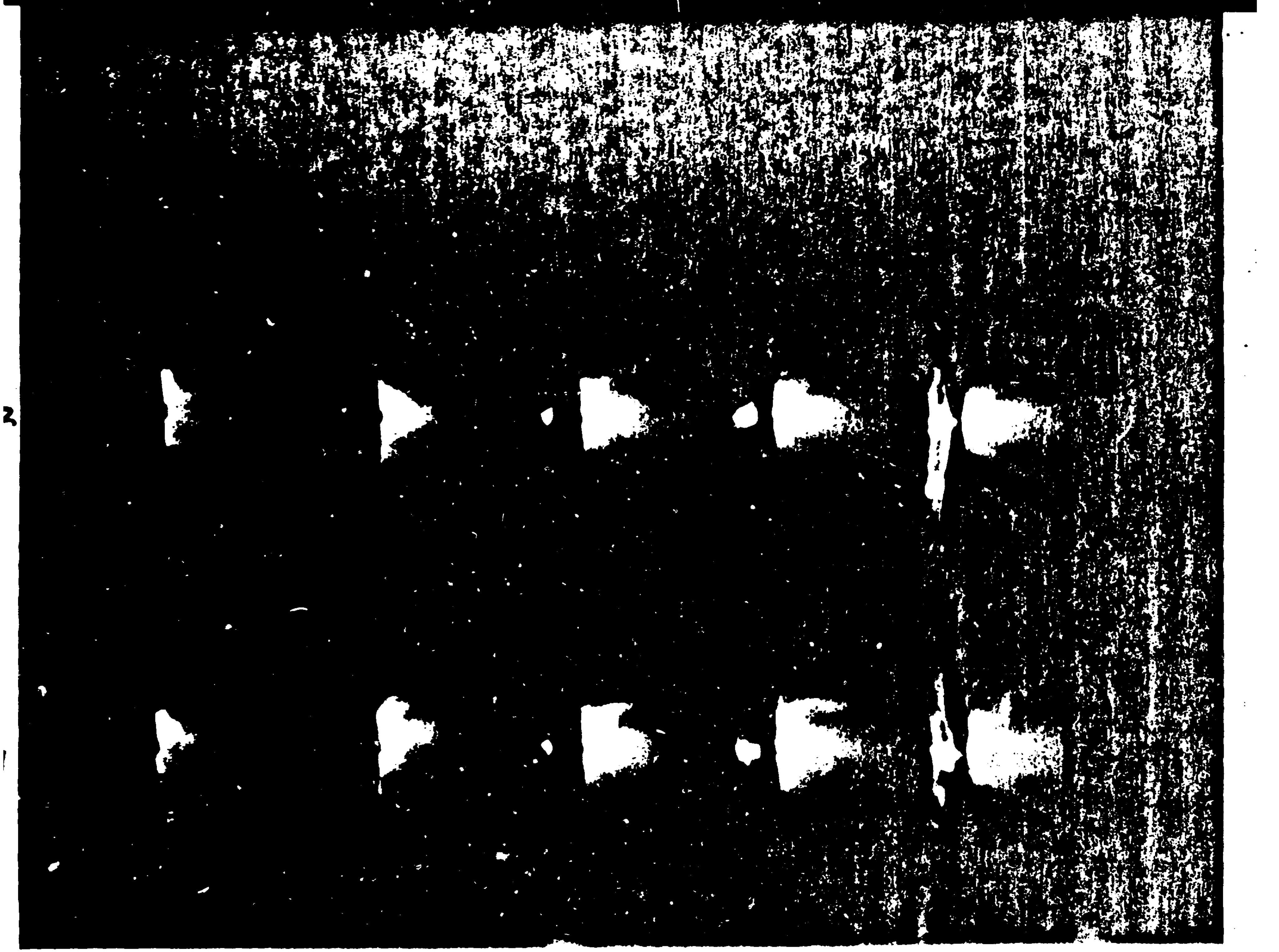
LPX I database, including predictions, 11/15/86
Al at vacuum, 0 degrees, lvi and shb included


PHOTODIODE ARRAY (KMS/LANL)
BLOWOFF PLUME
INCIDENT LASER PULSE
FILTER PLANE
PHOTODIODE PLANE
FND100 PHOTODIODE
IR BLOCKING FILTER (KG3 GLASS)
100
OHM
LOAD
COLLIMATING TUBES
RGW DRWG. KMSREV4
11/17.86

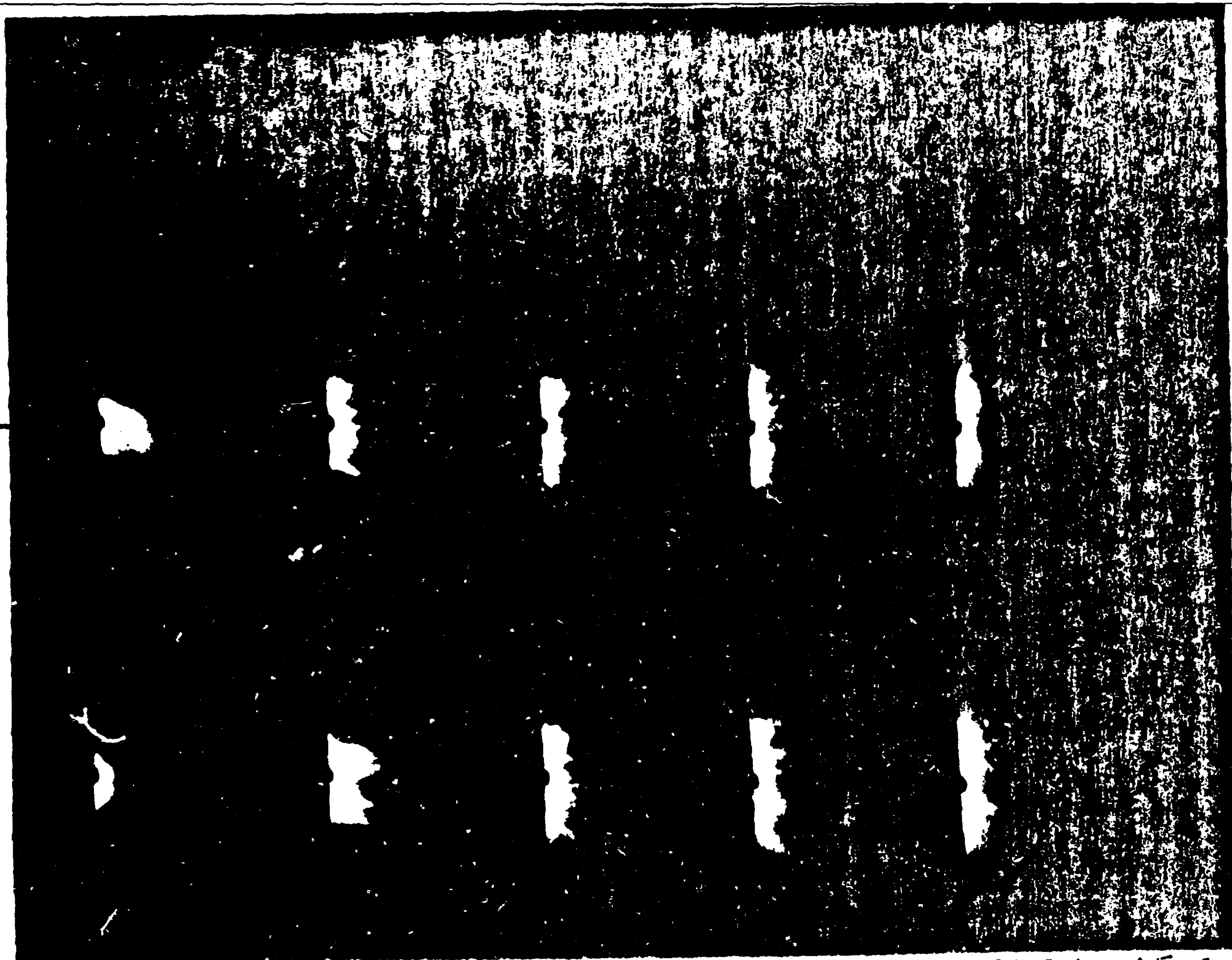
32 mm SPOT, 1.5 kJ, ALUMINUM



KMS00006

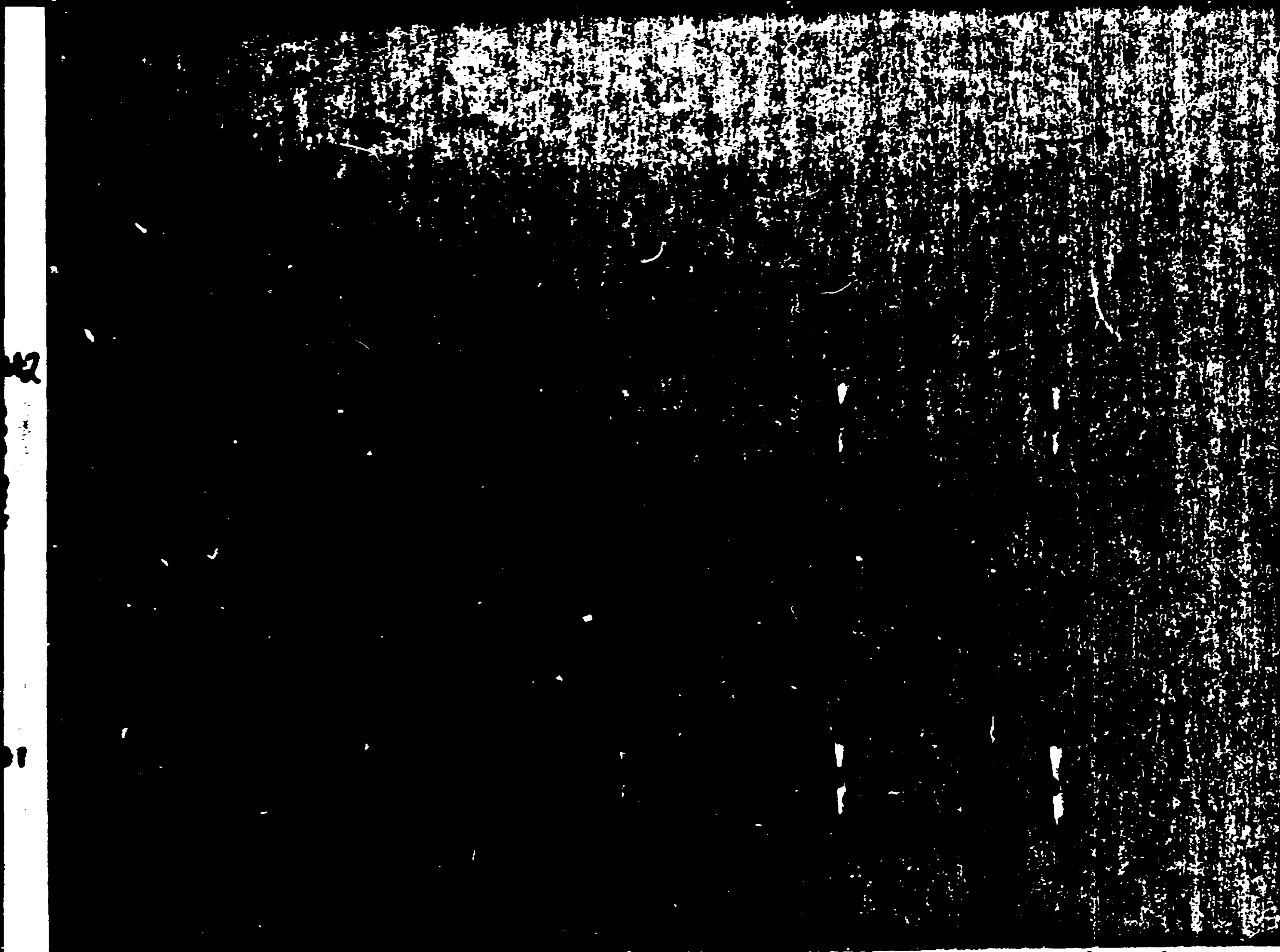


KMS062 2mm PU 2x10⁵ Head FRAME 1 - + 5μs 5μs INTERFRAME

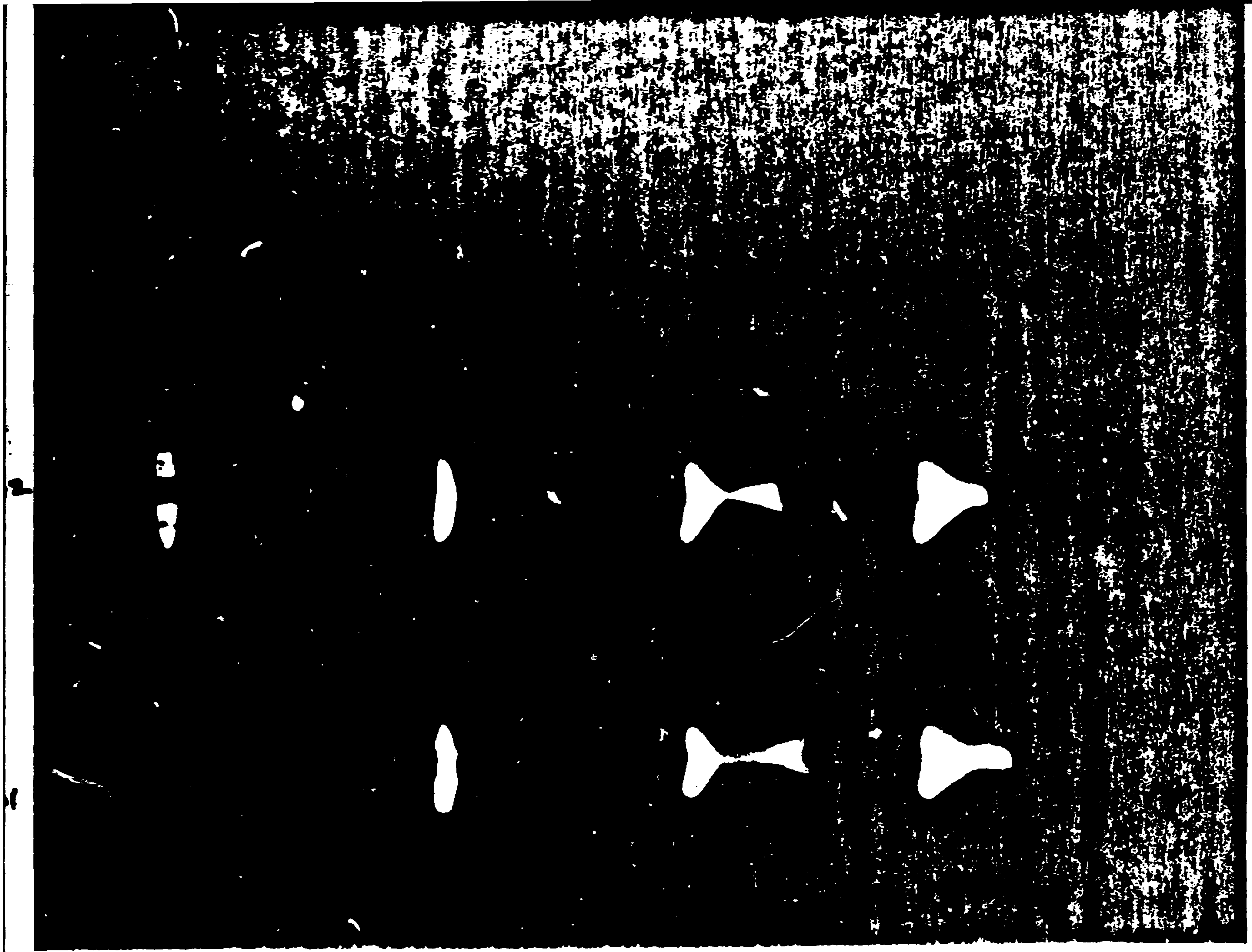


KMS061 2mm Gx 128μs 2x10^5 Head

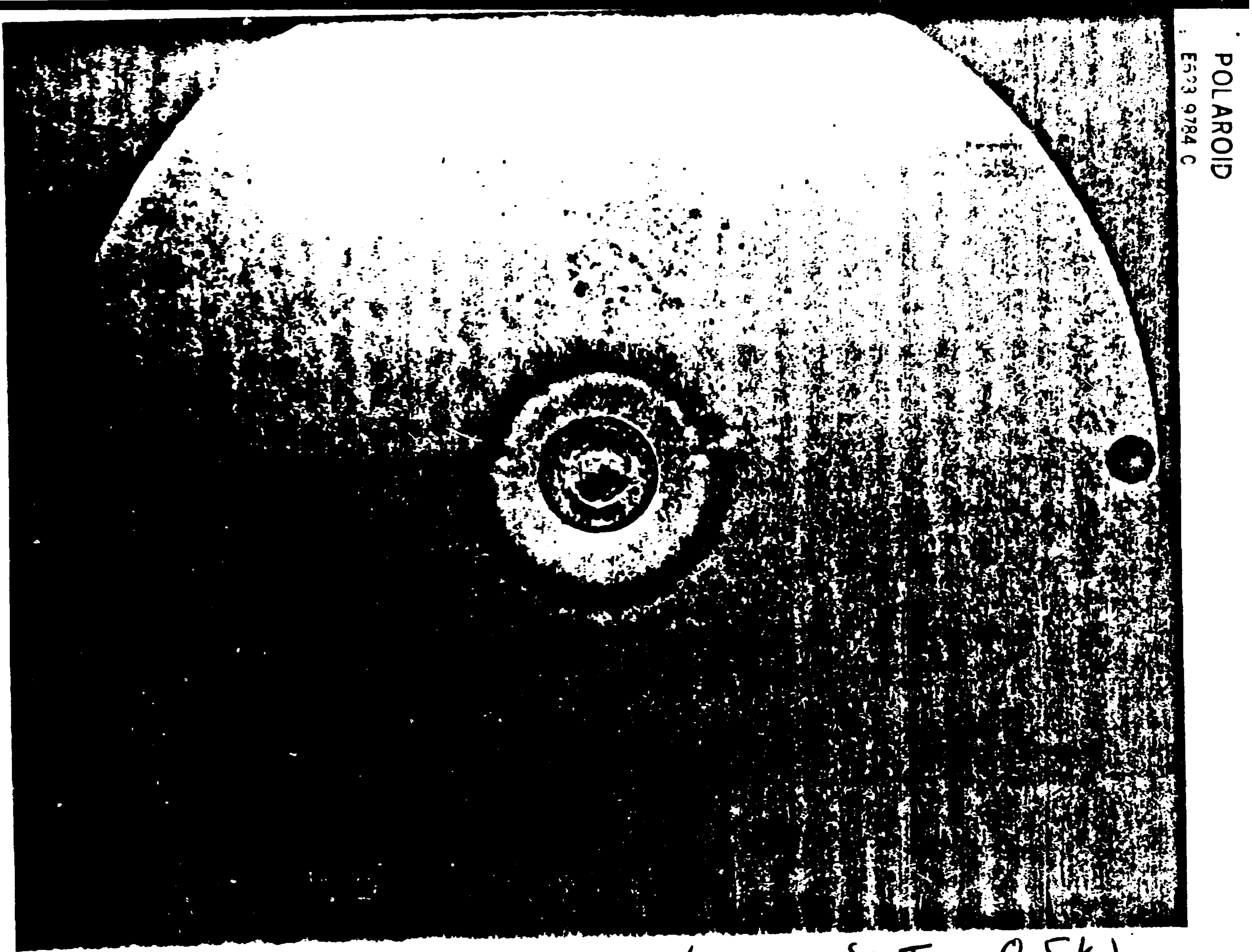
FRAME 1 - +5μs
5μs INTERFRAME



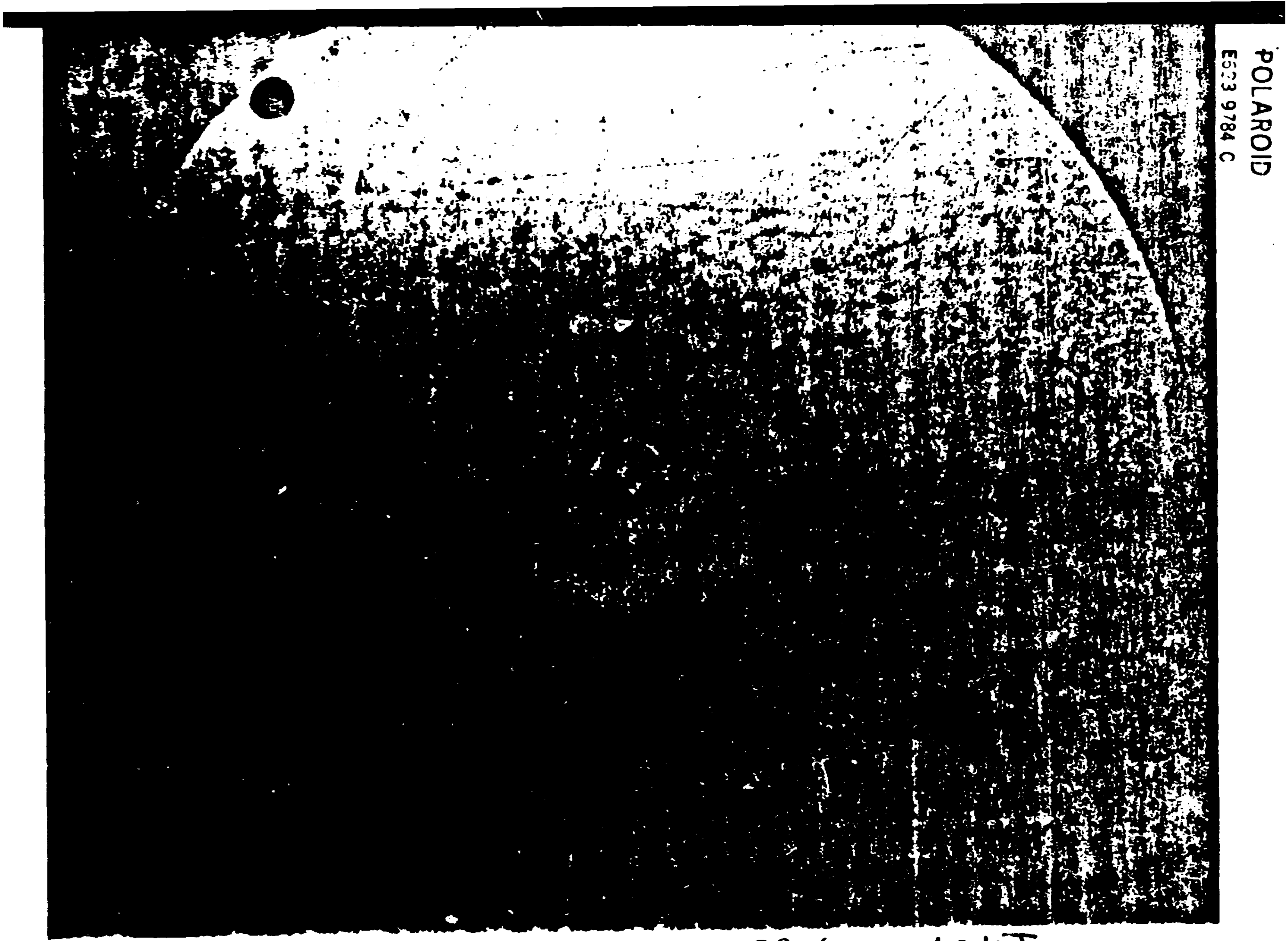
KMS060 2mm Al 128 μs 2×10^5 Head FRAME 1 - + 5μs 5μs INTERFRAME



KMS081 32mm AL 100ns INTERFRAME FRAME1 - +0.35μs

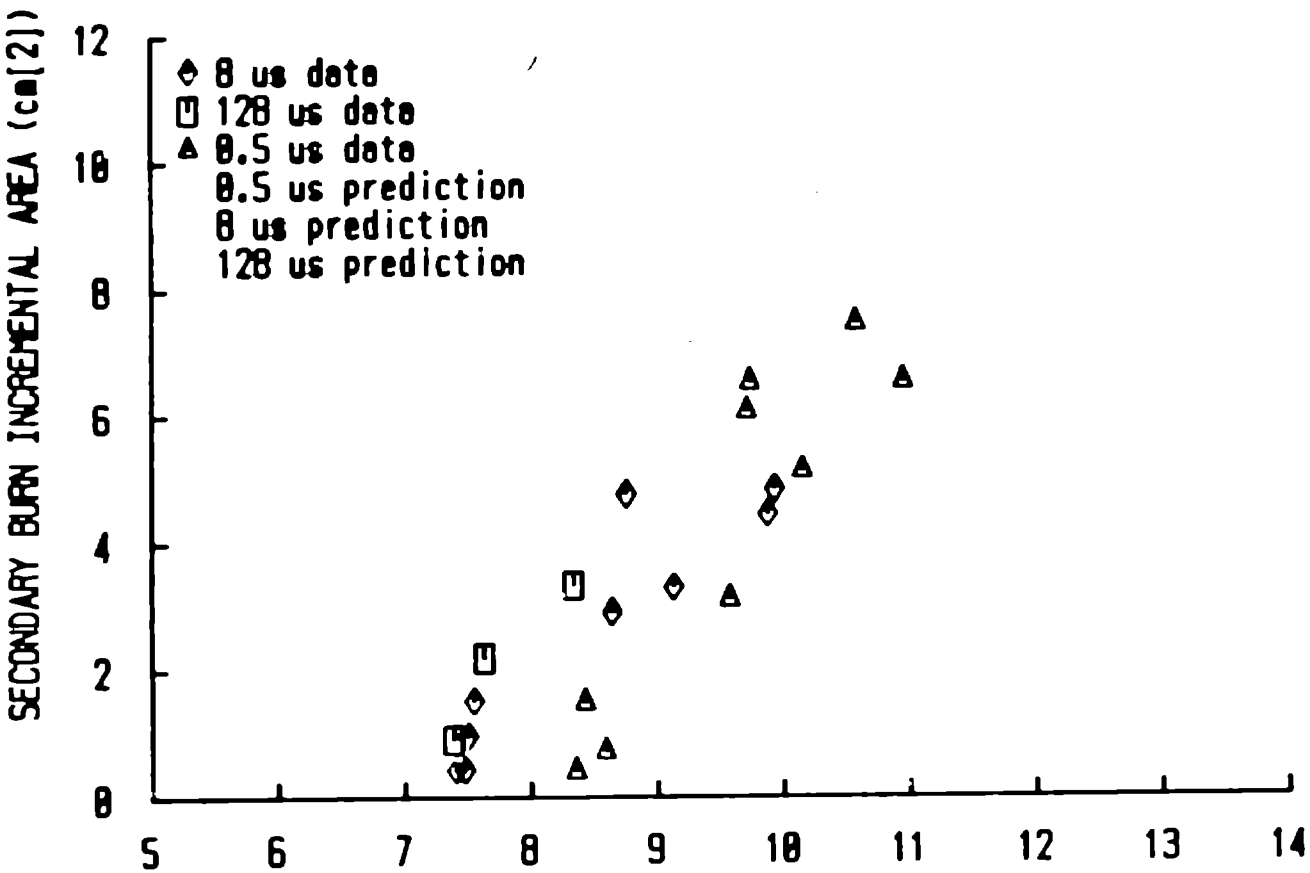


KMS 068 0.5 μs 6 mm SpoT 0.5 kJ



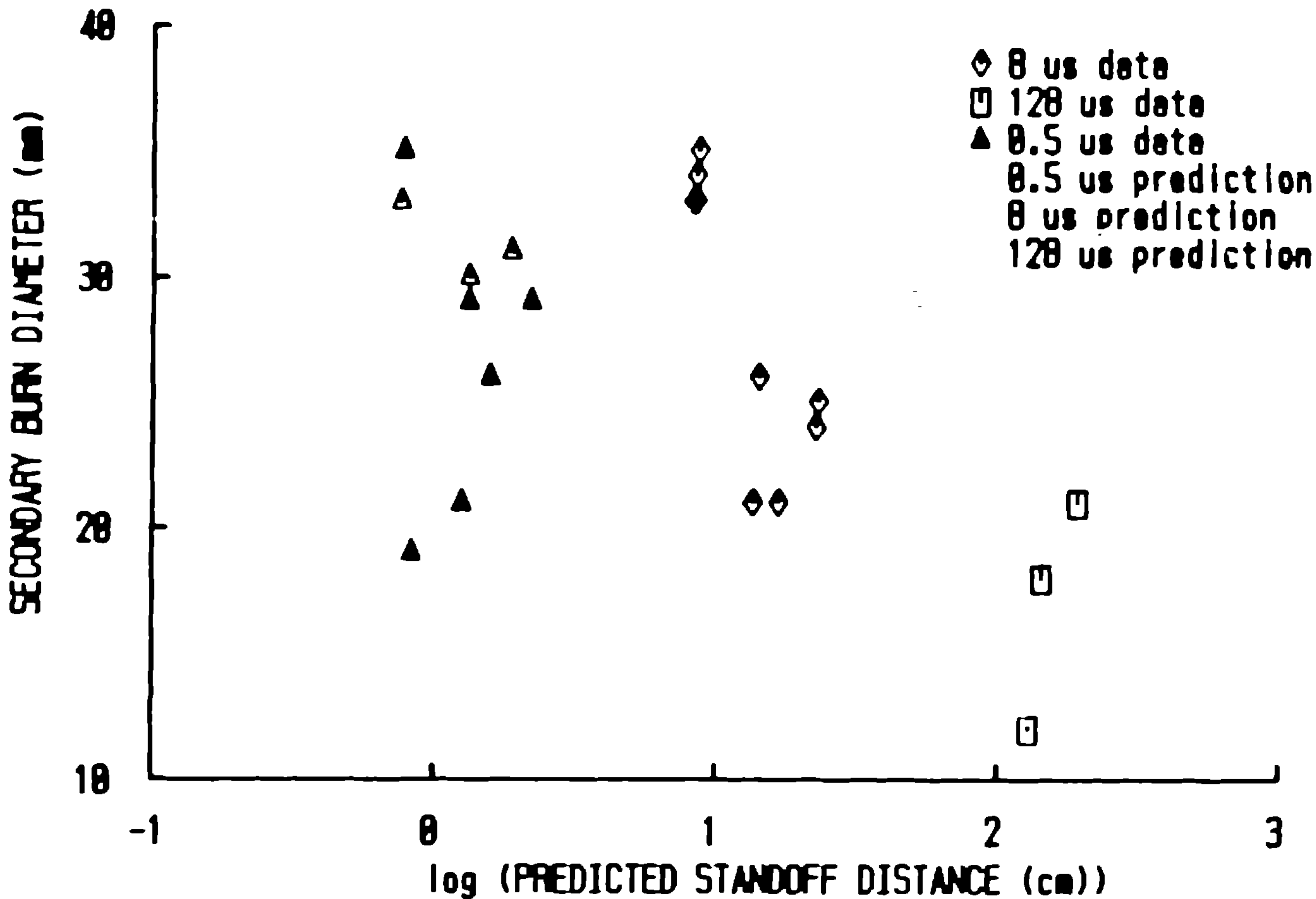
KMS074 0.5μS 3mm SPot 1.2KJ

The incremental area may coalesce to a universal curve above some secondary flux threshold for Al damage. A flux threshold is also consistent with the large very early radial expanse in the framing records.



LPX I database, including predictions, 11/15/86
Al at vacuum, 0 degrees, lvl and shb included

From a simple 1D model, one might expect that if any secondary burn occurred, it's radius should increase with an increasing predicted absorption layer standoff (VsTlaser) distance. The observed decrease may be due to 2D expansion.



LPX I database, including predictions,11/15/86
Al at vacuum, 0 degrees,lvi and shb included

CONCLUSIONS

- SHB/LVI DATA AGREE WELL WITH DUAL IMPULSE
- UP TO 50% OF THE CENTRAL MASS LOSS CAN REDEPOSIT ON THE OUTER ANNULUS
- I/F INCREASES WITH PULSE LENGTH, EVEN AT 1.054 U
- SECONDARY BURN MEASUREMENTS IMPLY 2D EFFECTS WERE DOMINANT
  2D->1D COMPRESSION EXPERIMENTS NEEDED

NEEDED FOLLOWUP EXPERIMENTS

- 2D->1D COMPRESSION EXPERIMENTS
  (APPLIED AXIAL B FIELD, ?)
  DUAL IMPULSE VS. FIELD
  BLOWOFF ANGULAR DEPENDENCE (IONS,
  NEUTRALS, PRESSURE)

- ANNULAR ENERGY DISSECTION
  (BULLSEYE CALORIMETER, IMAGING, ?)

- COMBINED INTERFEROMETRY/SELF-TRANSMISSION
  MEASUREMENTS

- EARLY TIME 100NS FRAME RATE
  PHOTOGRAPHY FOR LONG PULSE (PINCHING?)