FLASH X-RAY DEVICES FOR PUMPING NUCLEAR MATERIALS DEVELOPED IN THE GAMMA-RAY LASER PROGRAM AT TEXAS

C. Collins, F. Davanloo, T. Bowen, J. Coogan

To cite this version:

HAL Id: jpa-00227382
https://hal.archives-ouvertes.fr/jpa-00227382
Submitted on 1 Jan 1987

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
FLASH X-RAY DEVICES FOR PUMPING NUCLEAR MATERIALS DEVELOPED IN THE GAMMA-RAY LASER PROGRAM AT TEXAS

C.B. COLLINS, F. DAVANLOO, T.S. BOWEN and J.J. COOGAN

Center for Quantum Electronics, University of Texas at Dallas, PO Box 830688, Richardson, TX 75080, U.S.A.

Abstract - Progress in construction and scaling of a repetitively pulsed, flash x-ray device producing intense nanosecond pulses is described. This source would be used to excite nuclear fluorescence for the evaluation of candidate materials for a gamma-ray laser. For some applications these devices can offer a table-top laboratory alternative to laser plasma x-rays and to synchrotron radiation.

1. Introduction. - The developing availability of synchrotron light sources has stimulated major areas of research requiring pulses of radiation in the x-ray region. Average x-ray powers can now be great enough so that many experimental responses can integrate above the noise in reasonable working periods. Unique features such as the collimation of the output seem to render the synchrotron irreplaceable for many applications. Nevertheless, the imbalance between demand and supply of such facilities motivates the development of alternative sources for at least some applications not needing all of the synchrotron’s distinctive features. One such application of particular interest to our laboratory lies in examining the nuclear fluorescence from materials irradiated by x-rays[1]. Since we are using extended absorbers, collimation is not important. For us the essential figure-of-merit lies in the average x-ray power emitted over the bandwidth of interest in pulses of duration of the order of 20 nsec or less.

Although both laser plasmas and large e-beam discharges offer alternative solutions to the need for maximal emitted power in the x-ray region, those also are large and expensive devices requiring complex supporting facilities. A first major step in the realization of a laboratory scaled, pulse x-ray source was the Blumlein-driven generators of BRADLEY[2] and co-workers. For pulses as short as 100 nsec their devices performed successfully to the point limited by fundamental considerations, yet remained portable and self-contained. Nevertheless, those generators, together with e-beam devices, were characterized by very low repetition rates which would necessarily limit their usefulness in experiments dependent upon the integration of responses that occur with low probabilities.

Recently we reported[3] a further step in the realization of a laboratory scaled source of intense pulses of x-rays delivered at high rates of repetition. We described a Blumlein-driven x-ray diode for which impedances had been controlled to yield output pulses of about 10 nsec duration with reasonable efficiency. Moreover, commutation was effected with a hydrogen thyratron so that operation to high repetition rates could be realized. At 100 Hz an average x-ray power of 35 mW was reported. Here we describe the scaling of this type of device to yield 300 mW of x-rays while retaining the table-top aspects.

2. Device Design and Construction. - As described and shown in our previous reports,[3,4] the types of flash x-ray devices we are developing are apparently the first not to be choked at the head. The extremely low profile of our x-ray diode has resulted in an effective impedance of about 1-4D at the frequencies characteristic of those in the voltage waveform. Thus, the diodes are reasonably well-matched to the Blumlein during the most important part of the discharge of the current. As a result, the output pulses are found to have durations comparable to the transit times of the lines, an aspect not seen in previous devices. In fact, the combination of pulse duration and line impedance represents entry into a new region of parameter space, as shown in Fig. 1.
As described in previous reports, the design of the x-ray device centers around the three important subassemblies: 1) a low inductance x-ray tube, 2) a Blumlein power source, and 3) a commutation system capable of operation at high repetition rates. The basic organization of the flash x-ray device is shown schematically in Fig. 2.

In operation, the Blumlein was resonantly pulse charged with a source capable of operation in the range of 3-70 kV and repetition rates of 1-200 Hz. The middle conductor was charged to a positive high voltage which could be varied to 75 kV, and commutation was effected by a three-stage EG&G 5353 hydrogen thyratron mounted in a grounded cathode configuration.

The Blumlein boards were constructed from several thin Kapton (polyimide) dielectric layers. The smallest of the x-ray devices constructed in our laboratory, EXRAD, had a Blumlein line length of 1.2 m. The capacitor boards of this device were built with layers of Kapton dielectric, using high-dielectric oil between the layers. As the devices have been scaled upward in size and voltage, more substantial construction of the larger dielectric boards became necessary. This was accomplished by bonding the Kapton layers with epoxy cement. A very thin film of epoxy was applied between successive layers, taking care to roll out all the air bubbles from between them. The largest scale of the x-ray devices we have constructed, the FALCON-class module, had a 4.9 m Blumlein line length. The
TABLE I

Comparison of the dimensions and parameters of the Blumleins in the three devices used in these studies.

<table>
<thead>
<tr>
<th>System</th>
<th>EXRAD</th>
<th>Scale 0.33</th>
<th>EXRAD II</th>
<th>FALCON</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dielectric</td>
<td>Layered Kapton and oil</td>
<td>Layered Kapton and epoxy</td>
<td>Layered Kapton and epoxy</td>
<td>Layered Kapton and epoxy</td>
</tr>
<tr>
<td>Thickness</td>
<td>0.38 mm</td>
<td>0.69 mm</td>
<td>1.57 mm</td>
<td>.71 mm</td>
</tr>
<tr>
<td>C(storage)</td>
<td>9.5 nF</td>
<td>7.2 nF</td>
<td>5 nF</td>
<td>30 nF</td>
</tr>
<tr>
<td>A(storage area)</td>
<td>1283 cm²</td>
<td>3218 cm²</td>
<td>3218 cm²</td>
<td>9100 cm²</td>
</tr>
<tr>
<td>C_switched</td>
<td>9.1 nF</td>
<td>8.7 nF</td>
<td>5 nF</td>
<td>30 nF</td>
</tr>
<tr>
<td>A_switched area</td>
<td>1415 cm²</td>
<td>3470 cm²</td>
<td>3470 cm²</td>
<td>9400 cm²</td>
</tr>
<tr>
<td>Line impedance</td>
<td>0.85 Ω</td>
<td>1.8 Ω</td>
<td>3.6 Ω</td>
<td>1.65 Ω</td>
</tr>
<tr>
<td>Transit time</td>
<td>6.8 nsec</td>
<td>11.4 nsec</td>
<td>12.6 nsec</td>
<td>25.3 nsec</td>
</tr>
<tr>
<td>Applied Voltage</td>
<td>28 kV</td>
<td>35 kV</td>
<td>75 kV</td>
<td>35 kV</td>
</tr>
</tbody>
</table>

Comparative values of line dimensions and parameters for the various prototype devices used in this report are summarized in Table I.

3. Operation and Performances. - The outputs from two FALCON modules with dimensions and parameters indicated in Table I have been successfully synchronized. The x-ray intensities were recorded by means of a PIN photodiode with 1 nsec risetime connected directly to a Tektronix 7912AD digitizer without preamplification. Trigger pulses for both thyratrons were adjusted to bring the two x-ray pulses together in time and to produce a single x-ray pulse of doubled amplitude. The result is shown in Fig. 3. The two pulses of smaller amplitude are the x-ray powers from two FALCON devices where the trigger pulses were set to be about 400.

FIG. 3: Typical synchronization of x-ray pulse outputs from two FALCON-type devices.
50 ns apart. Synchronizing these two pulses produced a single large pulse as shown in the figure. Pulse energies of 6 mJ were available at 30 kV of applied voltage from the successful synchronization of two FALCON devices.

The scaling with operating voltage of the outputs from flash x-ray devices has been the recent subject of an excellent review[5]. As seen there, the x-ray output scales to approximately the cube of the voltage, meaning that the upgrading of voltage capabilities delivers higher levels of x-ray irradiation. Thus operations were extended to 75 kV of applied voltages by upgrading the older "scale 0.33" system as EXRAD II. The scaling of x-ray outputs to larger values with increased system size and applied voltage is shown in Fig. 4.

With the larger devices considered in this work x-ray pulse energies were found to remain largely constant as the pulse repetition rate was varied over the range from 1 to 200 Hz. Figure 5 shows this to be reflected in the measured values of average power output in the x-ray pulses from the largest of the devices. Limitations imposed by the primary power supply to the pulse charge system prevented the actual operation simultaneously at both the maximum values of repetition rate and at voltages higher than shown in the figure. However, the absence of any significant variation in output pulse energy with repetition rate indicates from Fig. 5 that average powers in excess of the 300 mW shown are readily within the capabilities of these devices.

Acknowledgements. - The authors gratefully acknowledge the support of this work by the Naval Research Laboratory with funds from the Innovative Science and Technology Program of the Strategic Defense Initiative Office.

References