

through the relay RLA, and its contact (RLA/1) discharged  $C_2$  through DM 50/2, stepping the wipers to positions 26 and 1 respectively. Thus this gave the required complete revolution of the wiper on receipt of 48 pulses at 30 min intervals.

#### Acknowledgments

The author thanks Mr D L Abbott for his interest in the work. Also Messrs E A Fribbins and K G Jones for the construction of the cam and collet, and Messrs R S Cole and K J Escott for help in construction of the programming board.

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## A 0–4 kv pulse amplifier for field ion microscopy

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**Abstract** A 0–4 kv pulse amplifier has been constructed for field ion microscopy. The circuit employed was a triode amplifier, powered by a 5 kv full-wave voltage doubler, triggered by a General Radio 1217-B pulse generator and capacitively coupled to the field ion microscope via a 30 kv, 0.01  $\mu\text{F}$  capacitor. The circuit produces either negative or positive field evaporation pulses. The usable minimum pulse time was found to be in the range 10–20  $\mu\text{s}$  for this amplifier design.

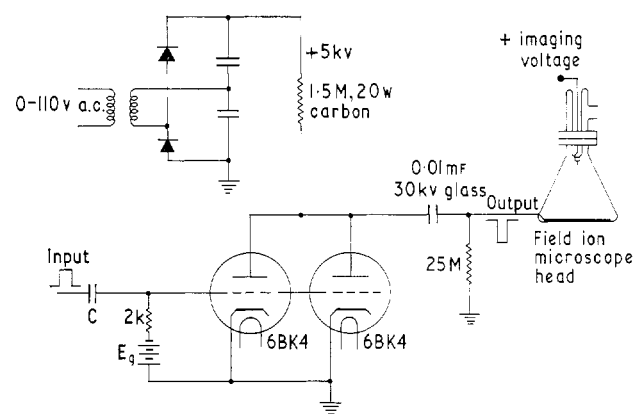
The final metallographic step in the preparation of a sharply pointed specimen for field ion microscopy involves the application of the physical process of field evaporation (Müller 1956). This process is normally accomplished by applying a constant controlled electric field to the specimen which is large enough to evaporate (desorb) metal atoms from the parent lattice at an imaging temperature typically in the range 4.2–80°K. In the field evaporation process the initially electropolished or etched specimen, which invariably possesses a sharp tip (50–100 Å radius) of rather uneven radius, is subjected to a high electric field. This high field selectively evaporates atoms from the regions of steepest curvature and effectively smooths the surface. A tip end form is eventually produced which consists essentially of a hemispherical cap of approximately uniform curvature.

In many of the applications of field ion microscopy (e.g. desorption studies, field evaporation kinetics, study of bulk point defects, etc.) it is mandatory to be able selectively to remove at a given time as few as one or two atoms from a specific crystallographic plane. This can only be readily accomplished by the use of a pulsed voltage, rather than a d.c. voltage, for field evaporation. This technique is accomplished by the addition of a square voltage pulse of known amplitude and duration to the so-called best-image voltage (Müller 1960). If the temporal width of the pulse is short relative to the integration time (approximately 0.1 s) of the human eye, the pulsed field ion microscope pattern appears as though it is at constant best-image voltage, and the undesirable image blurring (Tsong and Müller 1964, Weizer 1967a, 1967b)

which accompanies the application of a constant field evaporation voltage is totally absent.

In this note we report the details concerning an inexpensive and easily constructed pulse amplifier which we have employed in our laboratory for pulsed field evaporation experiments involving the study of point defects. This pulse generator produces pulses with amplitudes continuously variable from 0 to 4 kv† and with a pulse width continuously variable to approximately 50 ms. The use of a relatively expensive commercial high power pulse generator (model 350, Velonex Corp., Santa Clara, California) has been previously reported by Brenner (1965, 1968) and Petroff (1967 Ph.D. Thesis, University of California, UCRL Report No. 17633). The latter unit has a peak power of 20 kw. This power is considerably in excess of that required for many of the normal requirements of pulsed field evaporation and because of this fact, together with the price of the high power unit, the circuit described here was designed. Plummer (1968 Ph.D. Thesis, Cornell University, Materials Science Report No. 822) has constructed a 0–3 kv pulser with a pulse width which is variable from 10  $\mu\text{s}$  to 100 ms. The pulsing action of this unit is obtained by having the screen of the field ion microscope at a positive potential and then dropping the screen potential to ground potential. In addition Müller *et al.* (1968) have reported the use of a Huggins Laboratory Inc. pulse generator (model 961-E) for use with their atom-probe field ion microscope. This pulse unit produces a variable 0–3 kv, 2 ns wide pulse with a rise and fall time of 0.5 ns. A generator of this type is essential for the more stringent requirements of the atom-probe field ion microscope, while the amplifier reported in this note was specifically designed for the requirements of normal field evaporation work.

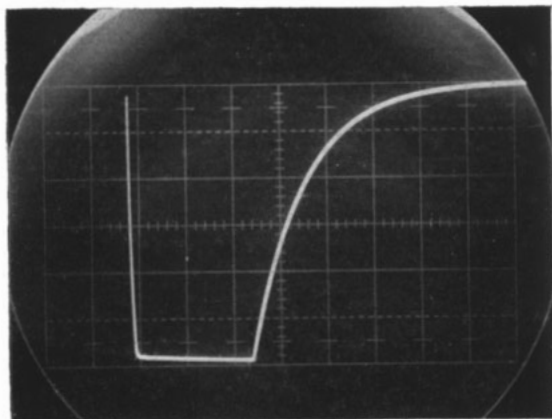
The circuit employed (see figure 1) was a triode amplifier (e.g. see Littauer 1965) powered by a 5 kv full wave voltage doubler, triggered by a General Radio 1217-B unit pulse generator, and capacitively coupled to the field ion microscope via a 30 kv, 0.01  $\mu\text{F}$  capacitor. The tube chosen for the amplifier was a 6BK4 (see Radio Corporation of America *Receiving Tube Manual: Technical Series RC-20*). This tube is a high voltage, low current, sharp cut-off beam triode with a gain factor of 2000. Two of these tubes were used in parallel



**Figure 1** Schematic diagram of the pulse amplifier circuit indicating the production of a negative pulse which is capacitively coupled to the screen of a field ion microscope

† We have also recently constructed a pulse amplifier capable of producing a 12 kv pulse by a simple extension of the amplifier design discussed in this note.

to avoid exceeding the maximum d.c. plate rating factor. The 0–5 kv, 5 mA, full wave voltage doubler employed for the tube plate supply is readily constructed or may be obtained from any number of manufacturers (e.g., Spellman High Voltage, Bronx, New York, Allied Radio, Chicago, Illinois). The 60 Hz voltage ripple in the output of the full wave voltage doubler is of no consequence as long as the pulse duration does not exceed approximately 50 ms. The voltage dropping resistors used in the plate circuit must be carbon resistors to avoid objectionable ringing effects which are produced by the inductance of the wire wound resistors. This circuit has been used to produce both negative and positive† voltage evaporation pulses. In figure 1 the circuit shows the production of a negative pulse at the field ion microscope screen; figure 2 is



**Figure 2** Oscillogram of a typical negative 3 kv pulse. The time scale (abscissa) is  $20 \mu\text{s cm}^{-1}$  and the voltage scale (ordinate) is  $600 \text{ v cm}^{-1}$

the oscillogram of a typical 3 kv negative pulse. The fall time (the time interval between the 10 and 90% amplitude points) is approximately  $4 \mu\text{s}$  and the pulse exhibits a slight ramp 'down' ( $\sim 50 \text{ v}$ ) but without any overshoot or ringing present in the pulse front. The usable minimum pulse duration time was found to be in the range  $10\text{--}20 \mu\text{s}$  for this particular amplifier. The control of the pulse repetition frequency (for the short pulses) and pulse duration were found to be independent of one another as long as the time between pulses was approximately  $150 \mu\text{s}$ .

The amplifier described has been used in our laboratory for a period of approximately 18 months in helium field ion microscope studies involving vacancies in quenched metals and irradiation experiments concerning self-interstitials. The design has proved to be quite satisfactory for the uncovering of the bulk point defects introduced into metal specimens by the latter techniques.

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† To produce a positive pulse the sign of the input pulse from the General Radio 1217-B unit pulse generator is simply reversed and the positive going output pulse is then connected to the point indicated as '+ imaging voltage' in figure 1.

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## An atomic beam oven with very low associated magnetic field

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**Abstract** An atomic beam oven is described which is suitable for high-resolution crossed electron-atom beam experiments. For an oven temperature of  $420^\circ\text{C}$  the associated magnetic field a distance of 1 in from the oven aperture is found to be less than 1 mg.

Many problems arise in the construction of a suitable source for the production of a well-defined neutral atom beam of a given element. The oven must be heated to a temperature that produces a vapour pressure in the range  $10^{-3}$  to 10 torr, and the oven material must not react to any appreciable extent with the source element. The substance in the oven may exhibit creep in the molten state and block the oven aperture. In addition, it may be necessary to maintain the aperture at a higher temperature than the main bulk of the oven in order to produce dissociation of an element which is otherwise in a molecular form when evaporated. A more serious problem in the crossed-beam type of experiments, where an atomic beam is crossed with a low energy (50 eV) electron beam, is that of the magnetic field produced by high oven heating currents interacting with the electron beam. Where the whole apparatus is otherwise maintained at a magnetic field level below  $0.1 \text{ mg}$  such magnetic fields must be minimized.

An electrically heated oven has been designed for alkali metals, which can operate up to a temperature of  $700^\circ\text{C}$  and which overcomes all the above problems and, in particular, has an extremely low residual magnetic field associated with its operation. The essential features of the oven are shown in figure 1.

The oven is machined from EN58E stainless steel and is fitted with an upper and lower heating element. These two heating sections are separated by a section of oven whose wall thickness is  $0.050 \text{ in}$ . Each heating element is contained