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Contents

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Contents

Contents

Contents

Contents

Contents

Contents

Contents

ABSORPTION OF RADIATION IN A TOWNSEND DISCHARGE

D.T.A. Blair and H.W. Whittington

Introduction One of the major secondary mechanisms contributing to electrical breakdown in gases is the photoemission of electrons at the cathode due to radiation produced in the gas. Absorption of such radiation by the gas itself may influence the magnitude of this effect. Previous measurements of relevant absorption coefficients have been made under uniform-field conditions by Raju et al.(1) in several gases, including nitrogen with $E/p \geqslant 116$ V cm^{-1} $torr^{-1}$ (E is electric field strength, p is gas pressure). The present work extends the range of such measurements down to E/p values of just over 50 V cm^{-1} $torr^{-1}$ in nitrogen, oxygen, and mixtures of these, and provides an indication of the wavelength of the radiation involved.

Apparatus The present experimental apparatus, shown diagrammatically in Fig.1, was essentially similar to that used by Raju et al.(1). Photons were produced in a Townsend discharge in the uniform-field primary gap A1 - C1, some of which passed through perforations in A1, G, B and A2 and caused electron emission from the cathode C2 of the detecting gap A2 - C2. The purpose of electrodes G and B was to prevent the escape of charged particles from the primary gap. The detecting gap as a whole could be moved axially relative to the other electrodes, and an absorption coefficient μ was obtained from observations of the consequent variation in detecting gap current I using the relationship(1)

$$I = I_0 \exp(-\mu d)$$

where I_0 is a constant and d is the distance A1 - C2. The derivation of this relationship takes account of the fact that the photons are produced at different positions in the primary gap.

In the present apparatus, the primary electrons for the Townsend discharge were produced within the electrode C1 by alpha-particle irradiation from an americium-241 source, a negative potential V_r being applied to a repeller plate to cause some of the electrons so produced to enter the primary gap through a gauze central portion of C1. This eliminated any possible difficulties with scattered light from an external ultra-violet source. The experiments were carried out using a non-self-sustained Townsend discharge. Filters could be inserted in the path of the radiation, in the space B - A2, by rotation of a rod passing through a rotary vacuum seal. Three different filter materials were used: ultra-violet glass with a passband of approximately 2500 - 3800 Å, vitreous silica with a cut-off at about 1700 Å, and lithium fluoride with a cut-off at about 1200 Å. An opaque screen partially enclosing the detecting gap reduced the effect of stray radiation from the primary gap which did not pass through the filter.

Experimental conditions In all experiments, the primary gap current was of order of 10^{-6} A. By adjustment of the voltage applied across A2 - C2, it was arranged that the detecting-gap current, which was normally gas-amplified, was of the order of 10^{-12} A.

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Experiments were carried out in the pressure ranges 2 - 80 torr in nitrogen, and 2 - 40 torr in oxygen and nitrogen-oxygen mixtures. All pressures have been reduced to equivalent values at 20°C. The nitrogen and oxygen were of cylinder grade, of nominal purity 99.9% and 99.5% respectively, and were introduced through a cold trap maintained at - 25°C, and dried over phosphorus pentoxide. Before any series of experiments, the experimental vessel was evacuated to about 10^{-5} torr and flushed with the gas to be used.

Absorption-coefficients measurements Values of μ were estimated from semi-logarithmic plots to a base of d of the ratio of detecting-gap current to primary-gap current: in this way the effect of spurious variations in primary-gap current was eliminated. Such plots were linear in all the present experiments, indicating a single value of μ under any condition, and therefore presumably monochromatic, or nearly monochromatic, radiation. Examples are shown in Fig.2. The range of d shown in Fig.2 of 2.40 - 4.40 cm was the same in all experiments. This is the distance from the upper surface of A1 to the surface of C2, i.e. the minimum distance traversed by the photons. Some of the experiments (in nitrogen, with gold cathode C2, $93 < E/p < 160$ cm^{-1} $torr^{-1}$) were repeated with the apparatus modified so that d varied instead from 5.40 to 7.40 cm. The plots were again linear and gave the same values of μ as the experiments reported here. This result was taken to indicate the absence of any appreciable geometric effect. Most of the experiments were carried out with a primary gap of 1.7 cm length. Since it was necessary to operate the primary gap very close to breakdown to obtain sufficiently high currents, wide variations in E/p could be achieved only by varying the gas pressure. Further experiments, with primary gaps of 1.9 cm and 1.2 cm allowed measurements to be made at fixed E/p with different pressures, and indicated that μ/p is a function of E/p only. It is considered that the values of μ/p quoted are accurate to $\pm$ 10%, and the values of E/p generally to $\pm$ 2% and nowhere worse than $\pm$ 5%.

Figs. 3 and 4 show results obtained in oxygen and nitrogen, using different materials for the cathode C2. It is not understood why there should be a discrepancy between the present results in nitrogen and those of Raju. Fig.5 shows results obtained in nitrogen-oxygen mixtures. These results indicate that μ increases progressively with increasing partial pressure of oxygen, and that the increase is most rapid at the lowest partial pressures.

Effect of filters When radiation from the primary gap was blanked off by a stainless-steel disc placed in the filter holder, a background current was measured in the detecting gap; this was generally of the order of 10^{-15} A and never greater than 7% of the current measured with the disc removed and no filter. This background current was presumably caused by stray radiation from the primary gap, since no current could be measured in the detecting gap in the absence of a discharge in the primary gap.

In all of the experiments reported here, a filter of ultra-violet glass or vitreous silica, placed in the path of the radiation, caused the secondary-gap current to fall to its background value. A filter of lithium fluoride caused the active radiation to be reduced by a factor of approximately 10 in all cases. These results indicate that in all cases investigated the active radiation has wavelengths of less than about 1200Å.

The radiation has, therefore, wavelengths comparable with those of the gas-ionising radiations investigated by Teich(2) and Sroka(3). Those authors report values of μ/p (for wavelengths in the region 1000 - 1200 Å) of the same order as those measured in the present work.

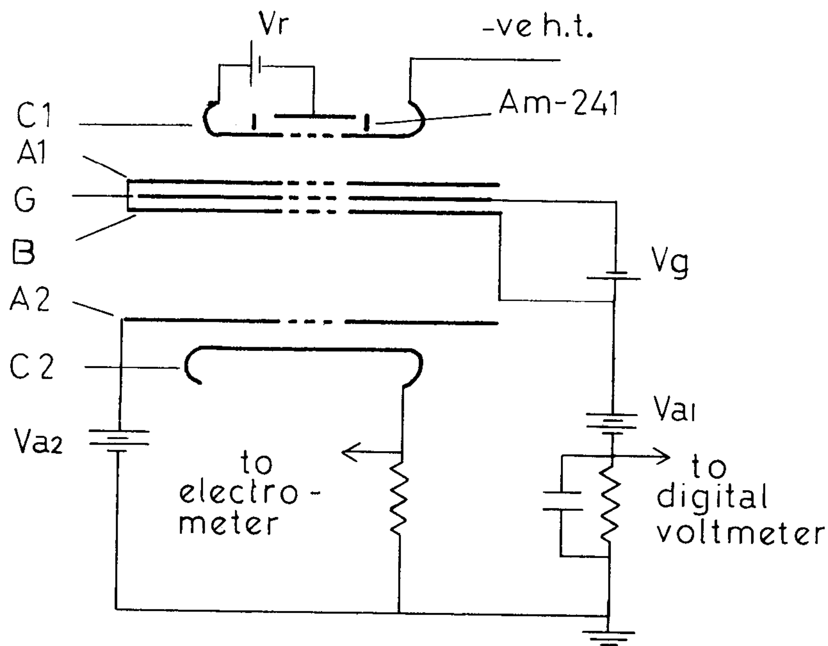

Fig.1 Apparatus

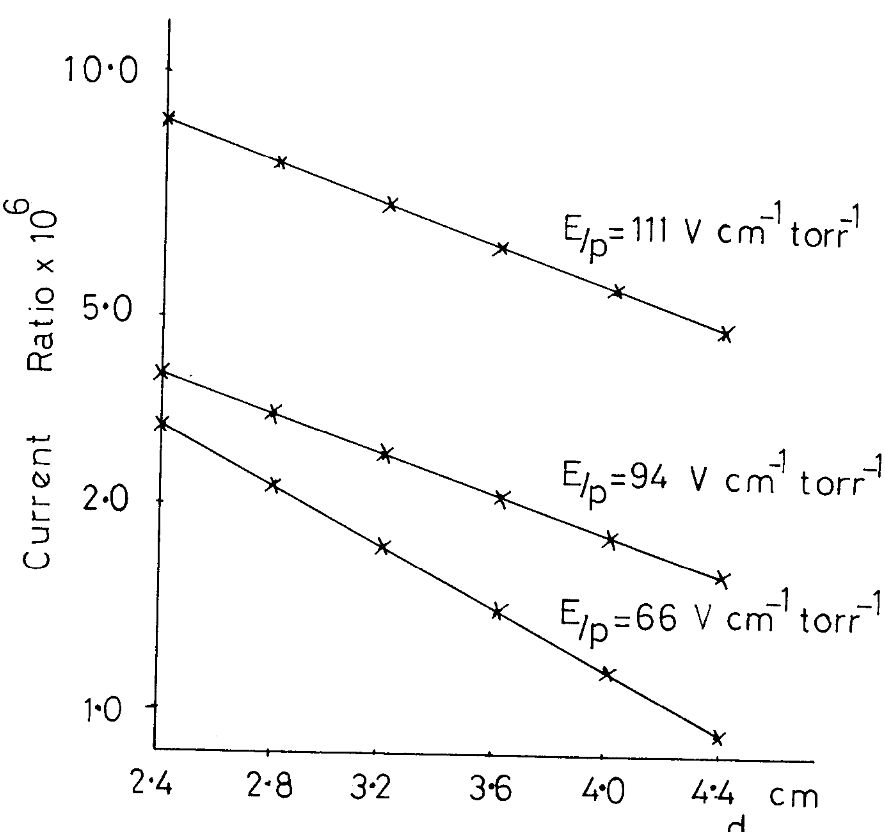

Fig.2 Experimental readings in oxygen

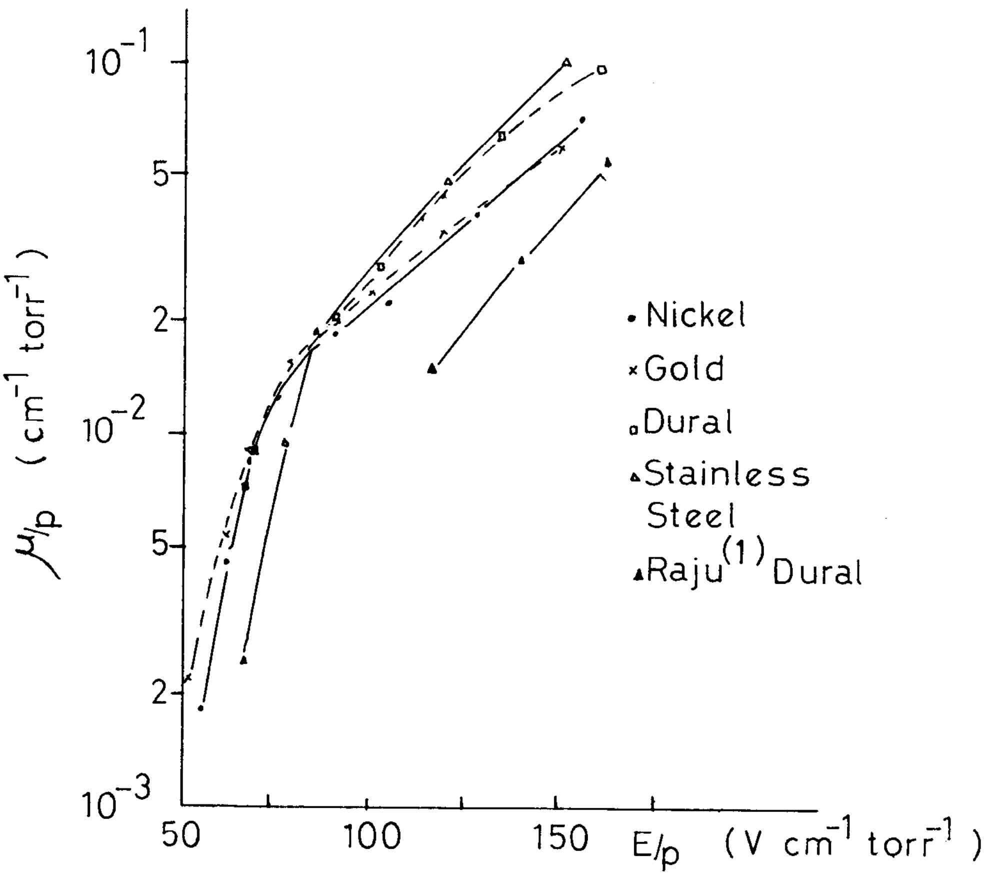

Fig.3 **Absorption coefficient measurements in nitrogen for different cathode materials**

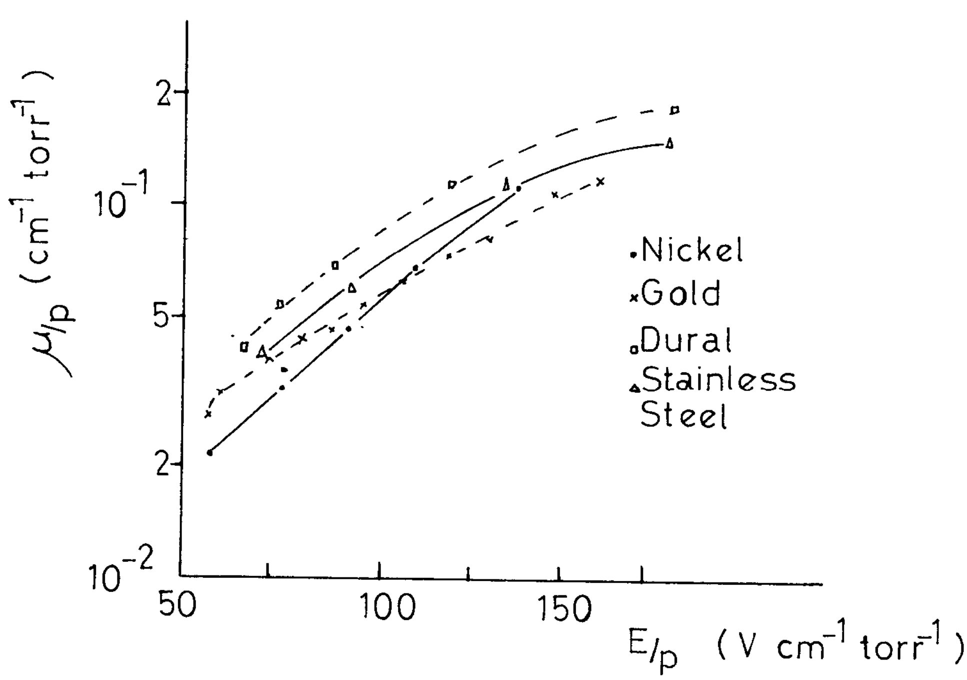

Fig.4 **Absorption coefficient measurements in oxygen for different cathode materials**

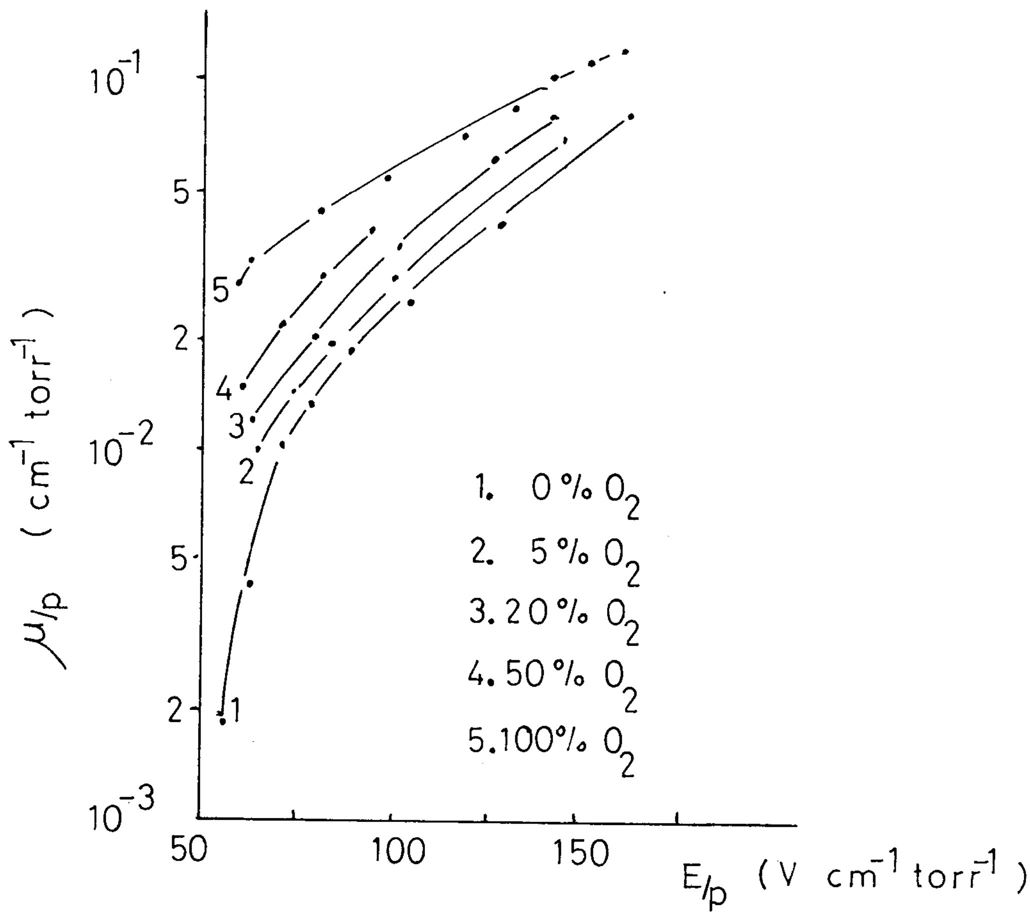

Fig. 5 Absorption coefficient measurements in nitrogen-oxygen mixtures with various percentages of oxygen. Nickel cathode.

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SPARK DISCHARGE TRIGGERED BY A PULSE LASER BEAM

K. Horii, T. Noguchi, M. Yano

Introduction The spark discharge in an air gap can be triggered by a giant pulse laser beam focused on an electrode surface. This type of gap is called the Laser Triggered Spark Gap, which can meet the need for a high speed switch of heavy current impulse generator. An experimental study of the breakdown mechanism of the gap was performed.

Experimental Arrangement A Q-switched ruby laser giving a pulse of 20 ns duration and of 130 MW peak power was used. The laser beam was focused with a lens of 11 cm focal length on the surface of spherical copper electrode through a hole (3 mm diameter) of the other electrode. Across the gap between the electrodes, a static voltage was applied by charging a capacitor connected in parallel with the gap. The laser beam pulse and electrical current pulses across the gap were measured with high speed oscillographs, Tectronics 519 and 517-A. Under the application of low voltage across the gap, even no voltage, two kinds of current pulses were detected as shown in Fig. 1. The current pulse which was detected simultaneously with the laser beam was named "the first wave", and the other was named "the second wave".

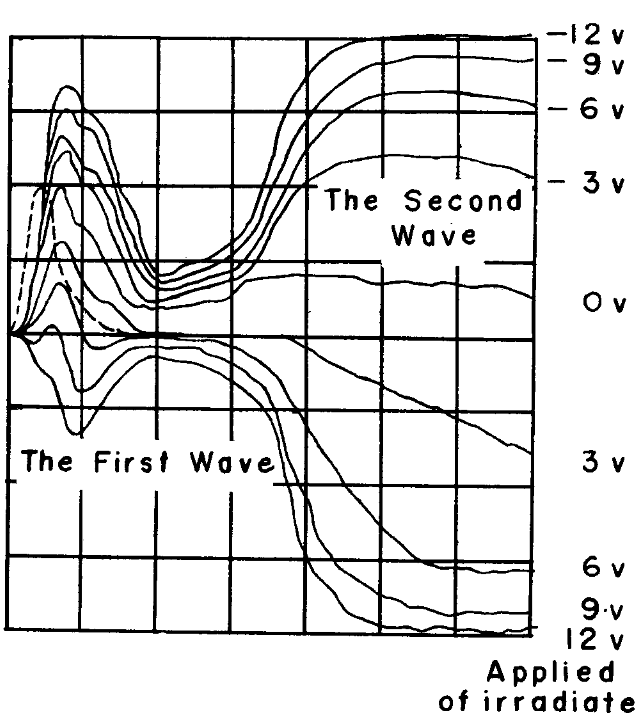

FIG. 1 Typical Electric Current Pulses and Laser Beam Pulses

Gap length : 2 mm
Laser power : 130 MW
Horizontal axis : 50 ns/div.
Vertical axis : 40 mA/div.

——— Current pulses
- - - - Laser beam pulse

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The First Wave The time lag T_1 of the first wave after the irradiation of laser beam pulse increased with the increase of gap length ℓ. For example, when ℓ increased from 1 to 5 mm, then T_1 increased from 10 to 20 ns. The velocity of the first wave is estimated from this time lag T_1 at the order of 10^7 cm/s. Fig. 1 shows that the time lag T_1 is independent of applied voltage but the peak value increases with the increase of applied voltage. As the laser peak power was attenuated, the peak value decreased while T_1 increased. For example, when ℓ was 2 mm and laser peak power decreased from 130 to 7.5 MW, then T_1 increased from 12 to 17 ns. Furthermore, the first wave propagated along the laser beam. The first wave was not detected when the laser beam was not focused on the surface but passed through the hole of the irradiated electrode. From the above-mentioned experimental results, the following two different mechanisms of the generation of the first wave are deduced;

1) The surface part of the metal plasma exploding from the irradiated electrode is accelerated by the laser beam, so that the plasma travels with a high velocity across the gap. The first wave is namely what is called "the detonation wave".(1)

2) The initial electrons generated by the ultra-violet rays from the exploding metal plasma are accelerated by the laser beam and ionized the air in the gap, as so-called "the precursor effect"(2) in the shock wave theory.

In order to exclude one of the hypotheses, the following additional experiment was performed. As shown in Fig. 2, a static voltage was applied across two plane electrodes having a hole respectively. Moreover, an irradiated metal piece was placed beside them. This metal piece was screened from the electrodes with a plate of quartz glass or a black paper. The laser beam passed through the holes was reflexed by two mirrors and focused on the surface of the metal piece. The plasma produced on the metal piece could not reach the gap between the electrodes but the ultra-violet rays from the plasma could, only in the case screened with the quartz glass. The first wave was detected only in case of quartz glass, so that the mechanism of generation of the first wave may be related to the second hypothesis.

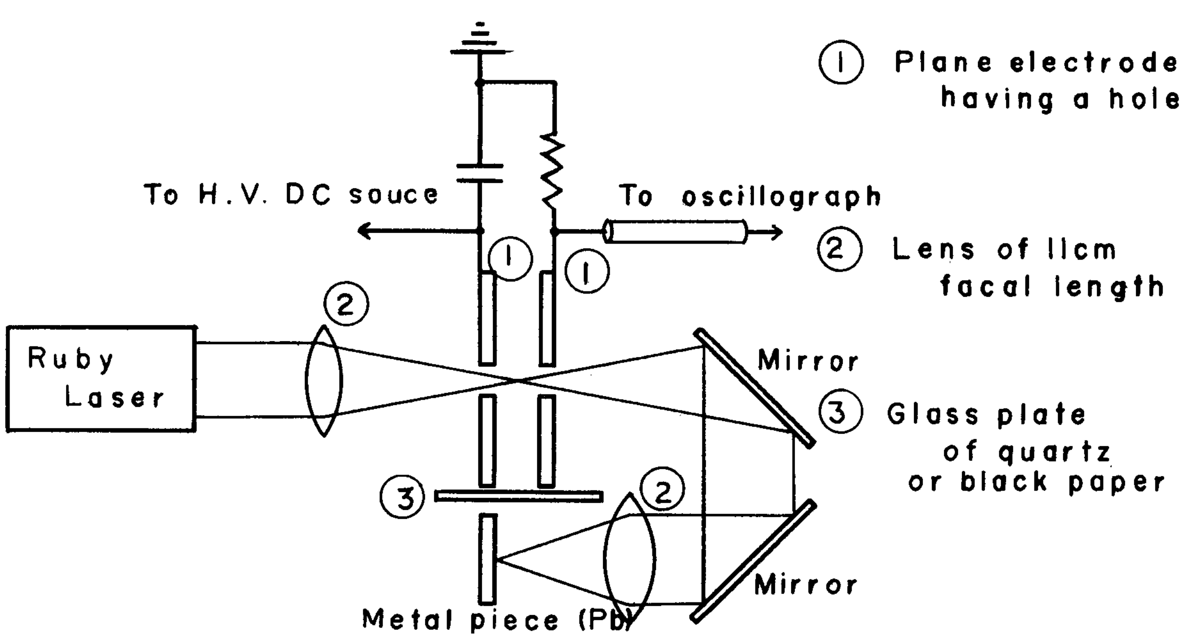

FIG. 2