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ABSOLUTE INTENSITY OF RADIATION EMITTED BY URANIUM PLASMAS

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April 1975

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16. Abstract

The absolute intensity of radiation emitted by fissioning and nonfissioning uranium plasmas in the spectral range from 350 nm to 1000 nm has been measured. The plasma was produced in a plasma-focus apparatus and the plasma properties are similar to those anticipated for plasma-core nuclear reactors. The results are expected to contribute to the establishment of design criteria for the development of plasma-core reactors.

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Uranium plasmas have applications in a number of experimental areas including gas-core reactors and nuclear-pumped lasers. The gas-core reactor is of particular interest as it offers an alternative to conventional solid-core reactor power plants. It is presently anticipated that the final model of the gas-core reactor will operate, with a fissioning uranium plasma as the core, at a temperature of about 50,000 K and ion densities of the order of 10^{20} cm^{-3}. Since the radiation emitted by the fissioning uranium plasma core will play an important part in the operation of such a reactor, a knowledge of the radiation spectrum of such a plasma is necessary in order to establish reliable design criteria for the reactor. The radiation emitted by uranium plasmas, containing both depleted U^{238} and enriched U^{235}, in the spectral range from 350 nm to 1000 nm, has been investigated with the objectives of: (1) determining the absolute intensity of the radiation emitted as a function of wavelength; (2) determining if any nonthermal radiation is produced by the plasma; and (3) determining if there are any detectable effects on the radiation spectrum due to induced fissions in the U^{235}. These measurements are the first laboratory data on the radiation emitted by uranium plasmas which are near the anticipated gas-core reactor conditions. Therefore, these measurements are expected to contribute to the establishment of design criteria for the development of plasma-core reactors.

The plasma which we investigated was produced in a 20 kilovolt, 25 kilojoule plasma-focus device.[1] The coaxial electrode arrangement is shown in figure 1. The uranium plasma was produced by inserting a disk of pure uranium metal into the tip of the center electrode (anode).[2] The device is normally operated at a filling pressure of 6.7×10^2 Pa (5 Torr) of deuterium. When the capacitor bank is discharged, a current sheet is formed and is accelerated upward between the electrodes by the $\vec{J} \times \vec{B}$ force. Maximum current is obtained as the current sheet reaches the end of the electrodes. The rapid radial collapse of the current sheet produces a dense, high-temperature plasma which emits intense bursts of charged particles and neutrons (from D-D reactions). The charged particles bombard the uranium sample creating the uranium plasma. The neutrons which are produced induce fissions in the plasma when U^{235} is used. Figure 2 shows the optical system used to make the measurements. The carbon arc was used as the radiation standard[3] and the calibration was made "in-situ." At each wavelength position a narrow band filter was inserted in front of the entrance slit to insure that no second-order radiation reached the monochromator. An exit slit width of 1 mm was used in these measurements corresponding to a band pass of 1.7 nm. The detector consisted of a high-gain photomultiplier tube and its output was recorded on an oscilloscope. All measurements reported here were made one half cm above the center electrode and at the peak intensity of the emitted radiation.

Figure 3 shows the experimental results obtained for the U^{238} and U^{235} plasma. Each experimental point represents the average of a large number of shots. Within the experimental error there is no observable difference in the two spectra.

Figure 4 is a comparison of these experimental results with blackbody curves as well as the results obtained from a laser produced U^{238} plasma.[4] These experimental results do not match any of the blackbody curves in this region. This is not surprising due to the existence of temperature and density gradients in the plasma. The blackbody curves should, however, provide some basis for comparison in this region.

No nonthermal radiation from the plasma was observed in this region. Also, no effects on the spectrum which could be attributed to induced fissions in the U^{235} were observed. This last result was anticipated as the energy due to the total number of induced fissions is small[2] compared to the total energy of the plasma.

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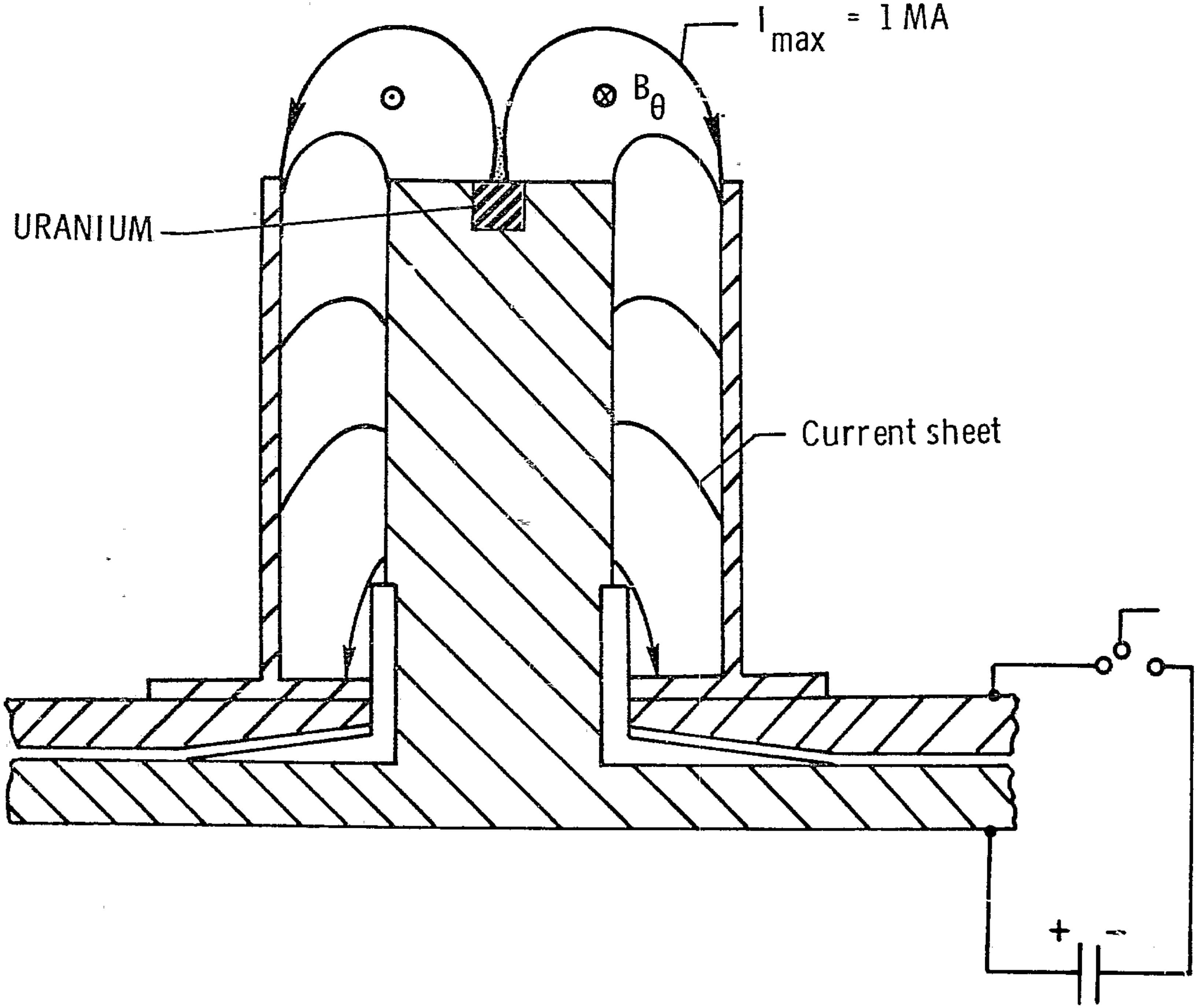

FIGURE 1. PLASMA FOCUS ELECTRODE ARRANGEMENT.

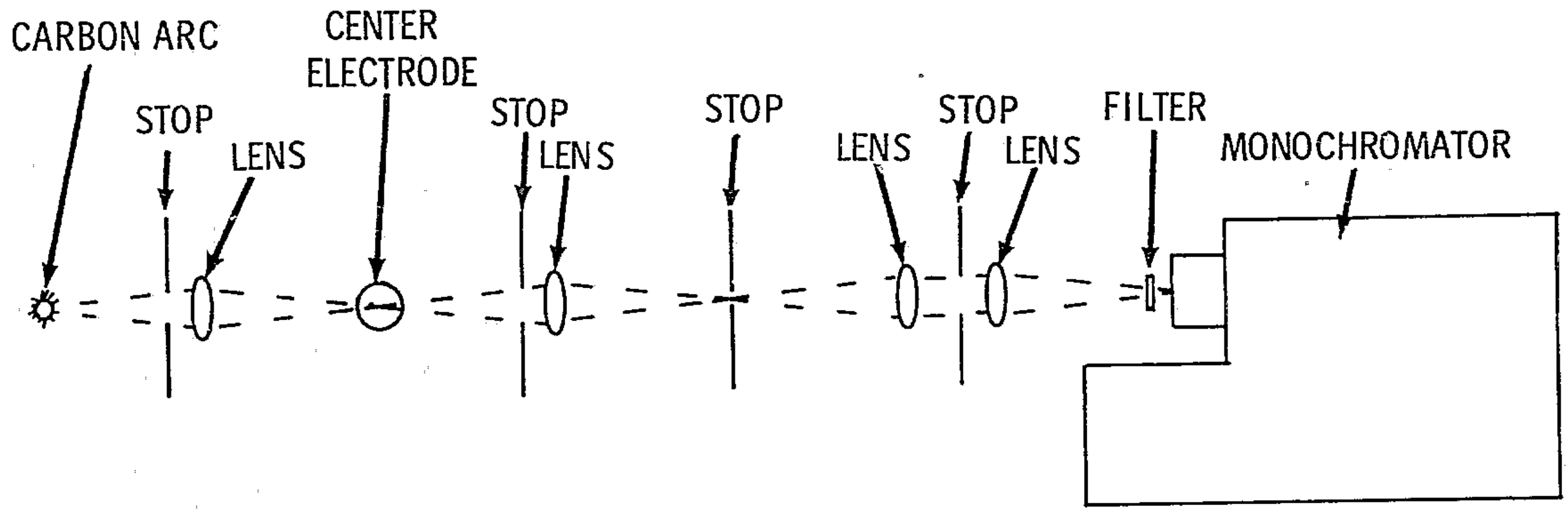

FIGURE 2. OPTICAL SYSTEM.

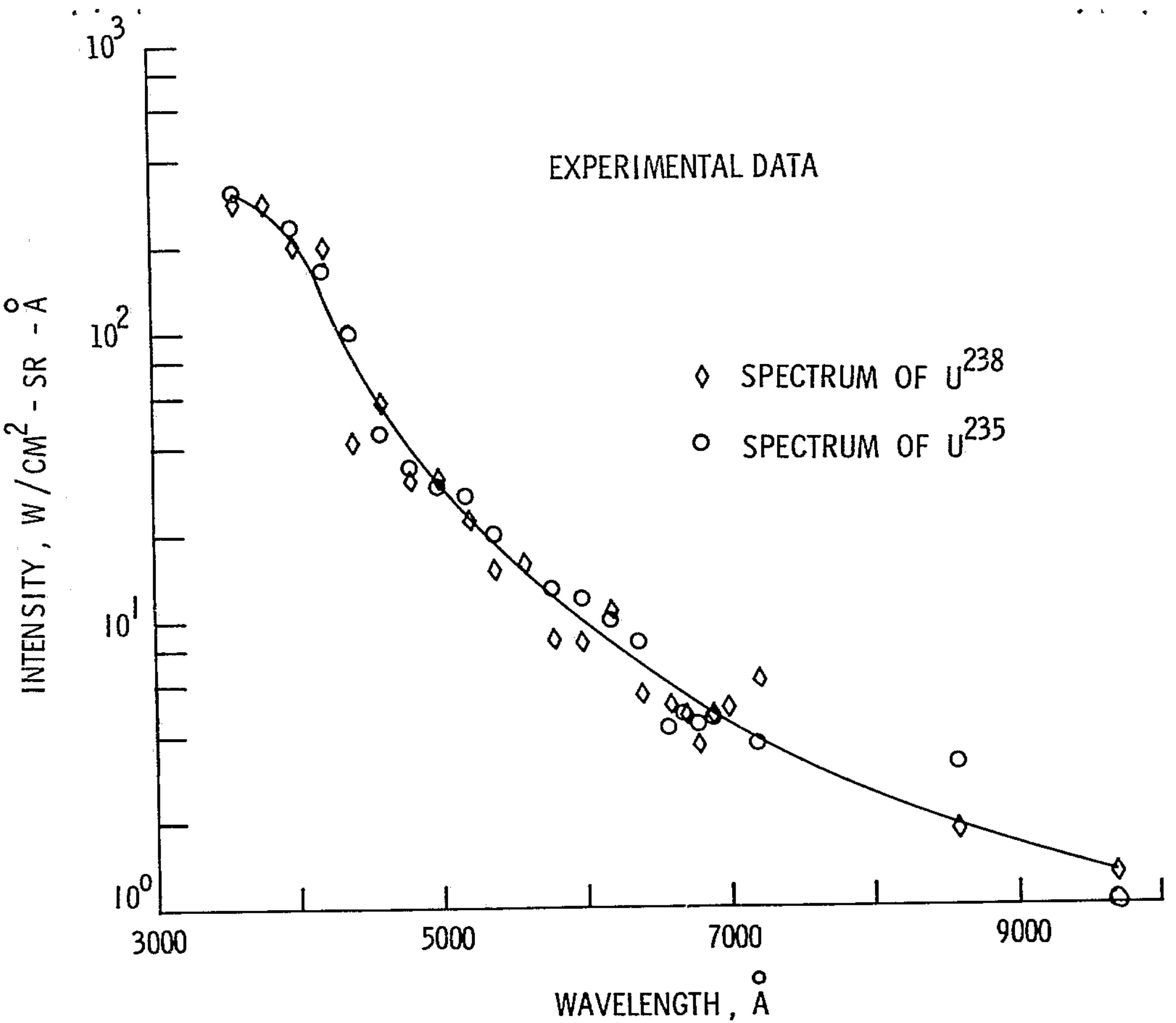

FIGURE 3. ABSOLUTE INTENSITY OF URANIUM PLASMA.

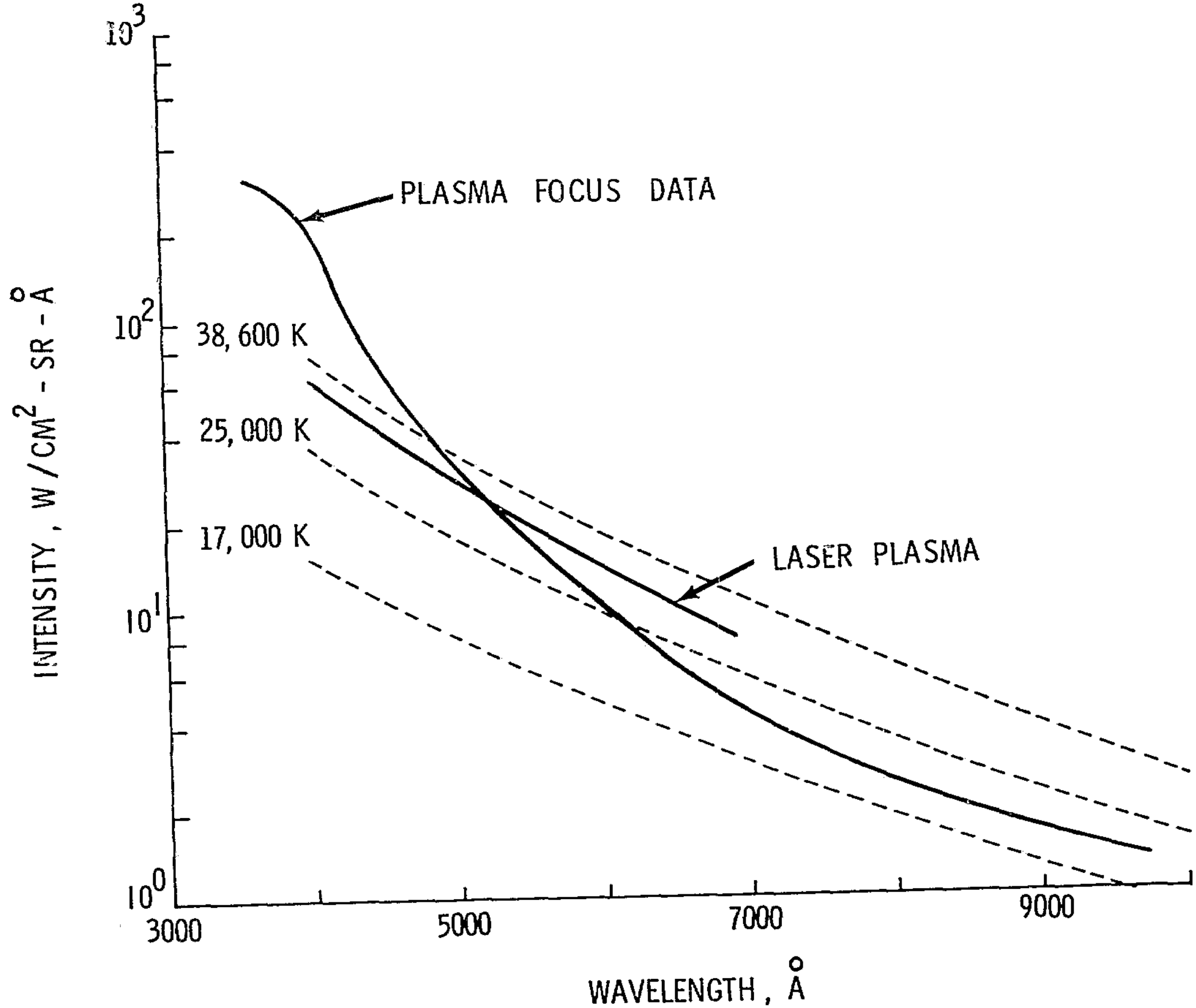

FIGURE 4. COMPARISON OF EXPERIMENTAL DATA WITH BLACKBODY INTENSITIES.