Characterization of argon arc source in the infrared

J. M. Bridges and A. L. Migdall

Abstract. A wall-stabilized arc source is being investigated as a radiometric source for the near- and mid-infrared spectral range. This arc is similar to the argon mini-arc, which has been used as a radiometric source in the ultraviolet. The potential usefulness of the arc in the infrared (IR) range stems from its high brightness in this region. The arc has been tested as a source for a recently constructed facility for calibrating IR detectors. Over the range 3 μm to 11 μm, the signals with this source were greater by a factor of 6 to 17 than the signals from a 1500 K ceramic element, despite the beam from the arc being smaller in angular extent. The radiance of the source was calibrated from 1,6 μm to 10,6 μm via a 1140 K black body. Over most of this spectral range the radiance of the arc is equal to that of black bodies ranging in temperature from 5000 K to 10 000 K. From 1 μm to 3 μm, a spectral scan with relatively high resolution shows a spectrum dominated by strong Ar I line emission. Finally, measurements were made of radiance as a function of arc current and translational position of the source.

1. Introduction

Measurements of infrared (IR) signals are often characterized by low signal-to-noise ratios. A stronger source than those commonly available would be useful in radiometric work such as the testing and calibration of IR sensors. The wall-stabilized arc source operating in argon has been observed to have a high brightness in the near- and mid-IR spectral region. A relatively low-powered version (1,2 kW) of this device has been developed and has been widely used as a standard radiometric source for the ultraviolet/vacuum-ultraviolet (UV/VUV) spectral region [1]. Similar arcs operating at higher power, up to about 7 kW, have also been useful where greater intensity is required. We have made measurements to characterize an arc operating at 6,5 kW in the infrared spectral range, which is potentially useful as an intense source for the near- and mid-IR range. In particular, this arc has been tested as a source for a comparator designed to calibrate detectors in the mid-IR range. This report gives some results of study, now in progress, to characterize the source, and possibly to develop it further for radiometric work in the IR region.

2. Apparatus

The radiation source is a wall-stabilized arc, a gas discharge in which the plasma between two electrodes is constricted to a cylindrical channel formed by holes in a stack of electrically insulated, water-cooled copper discs. Figure 1 is a cross-section of the source. The arc

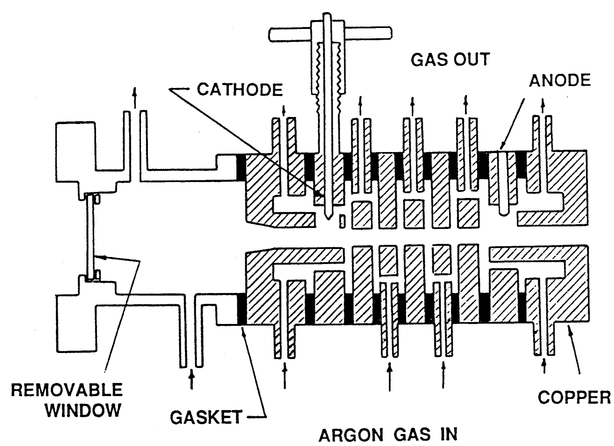

Figure 1. Schematic cross-section of the argon arc radiation source.

operates in a 4 mm diameter channel between two tungsten electrodes. The copper plates are 6,3 mm thick and are separated by silicone rubber insulating gaskets 1,5 mm thick. The arc chamber is not sealed, but is maintained at ambient atmospheric pressure with a constant, gentle flow of argon into several ports at 5 l/min. A window may be used to seal the arc to a volume of different pressure or gas composition, but these measurements were made without a window, so that argon flowed out of the front of the chamber in addition to other gas outlet ports. The arc can be operated at currents from 20 A to at least 100 A, using a current-regulated power supply. The arc is initiated by briefly shorting the electrodes by a tungsten rod. The movable cathode is temporarily moved inwards to facilitate ignition, after which it is withdrawn from the optical path. Although a resistor of 0,25 Ω is used for ignition, the arc requires no ballast during

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operation. For the observations reported here, two different spectral instruments were used. The spectrum was scanned in the near-infrared with a 0,25 m, f/3,5 grating monochromator equipped with a cooled PbS detector. For other measurements, an f/4 prism-grating monochromator equipped with a HeCdTe detector was used [2]. This recently constructed instrument was designed as a facility for calibrating infrared detectors. One purpose of the work described here was to test the argon arc as a source of radiation for this facility.

3. Infrared spectrum

Radiation from the stabilized arc is observed end-on, along the direction of the arc axis. The optical path for all measurements included approximately 1 m length of air. For scanning the near-IR spectrum, the arc plasma was focused onto the monochromator entrance slit with a concave mirror constituting an f/10 system. The spectral resolution was 2 nm. The spectral scan is shown in Figure 2. The portion above 2 μm was taken with increased gain. The spectrum is dominated by atomic Ar I line emission. One scan was taken digitally by sampling the signal over short time intervals during a continuous wavelength scan. These data were convoluted with functions representing larger bandpasses to show how the spectrum would appear with different values for spectral resolution. Figure 3 is an example of such a convolution for a bandpass of 50 nm. In this case, the lines are sufficiently blended to make the signal vary smoothly with wavelength. On the other hand, for a resolution sufficient to resolve the spectral lines, this source could be useful for wavelength calibration as well as for IR irradiation.

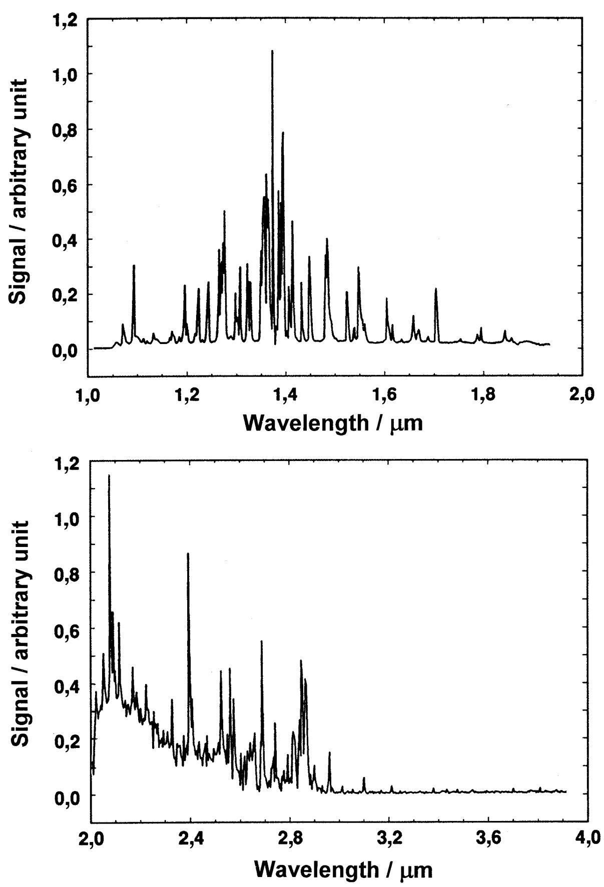

Figure 2. Photoelectric scan of argon arc spectrum in the near-infrared taken with 2,0 nm spectral resolution.

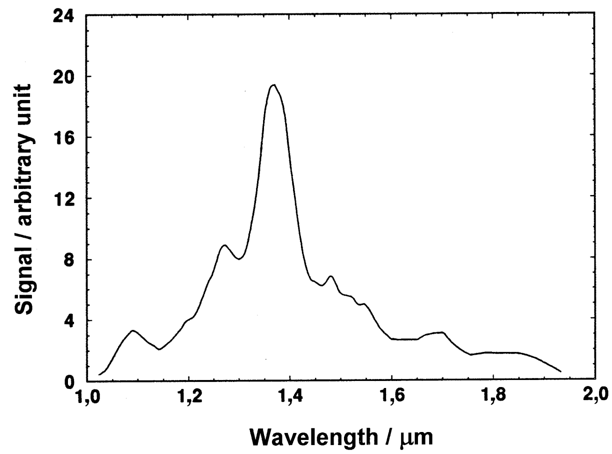

Figure 3. Convolution of argon arc spectrum between 1 μm and 2 μm with triangular function representing a bandpass of 50 nm.

Figure 4 shows relative signals from the f/4 prism-grating monochromator when irradiated by three different sources, a 1500 K ceramic element, the argon arc described above (6,25 kW), and a shorter, lower-powered arc, the argon mini-arc. For this comparison, the radiation was focused by two parabolic mirrors, and each source was positioned for maximum signal. These data were taken at discrete wavelengths (more points were taken from the maxi-arc). The circular entrance aperture for the monochromator was 1 mm in diameter,

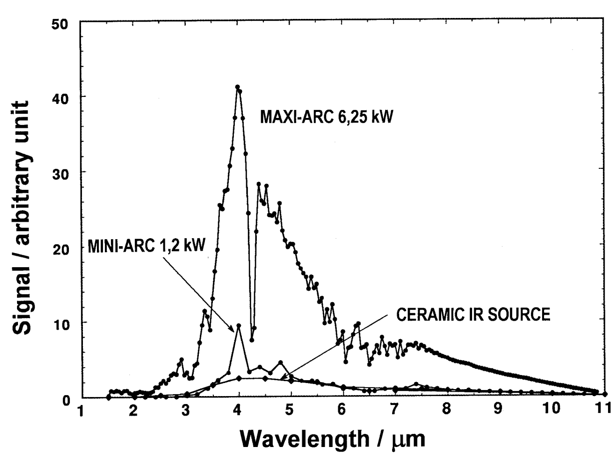

Figure 4. Signals from ceramic element, 1,2 kW argon arc and 6,25 kW argon arc, measured on prism-grating monochromator with HgCdTe detector.

resulting in a spectral resolution of 1%. While the mini-arc and ceramic element gave approximately equal signals for most wavelengths, those from the maxi-arc were up to 17 times greater.

4. Radiance calibration

The argon arc radiance was calibrated via a black body in order to obtain quantitative values. For this calibration the prism-grating monochromator was again used with a 1 mm diameter entrance aperture, but with an illumination system consisting of two plane mirrors and one spherical mirror. A 1 mm diameter area from each source was focused into the monochromator with unit magnification. By using different sized apertures at the focusing mirror, signals from each source were taken for optical beams of f/34, f/17 and f/11. The signal ratios from the two sources were essentially constant for these different conditions. Figure 5 shows the calibrated radiance of the argon arc at a current of 90 A, and the calculated radiance of the black body at 1140 K. Also shown are calculated radiance values for black bodies of 5000 K and 10 000 K; the argon arc radiance varies between these values over most of the spectral range 3 μm to 10,6 μm. As before, the spectral resolution of the monochromator was about 1%. At this resolution, the radiance of the arc varies smoothly with wavelength. The 2σ uncertainty of this radiance measurement is estimated to be 7%.

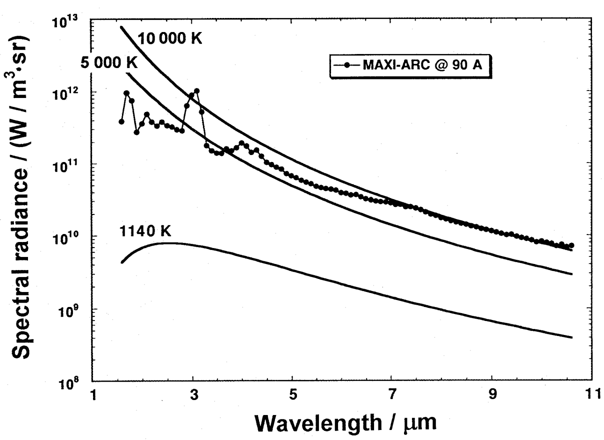

Figure 5. Spectral radiances of 6,25 kW argon arc and 1140 K black body used for calibration. Also plotted for comparison are calculated radiances of black bodies of 5000 K and 10 000 K.

5. Arc characteristics

Figure 6 shows the relative arc radiance as a function of current from 20 A to 100 A. Measurements were taken for wavelengths of 4 μm and 8 μm. There is only a slight difference for the two wavelengths. Both curves show an approximately linear increase of radiance with current above a threshold of ~20 A.

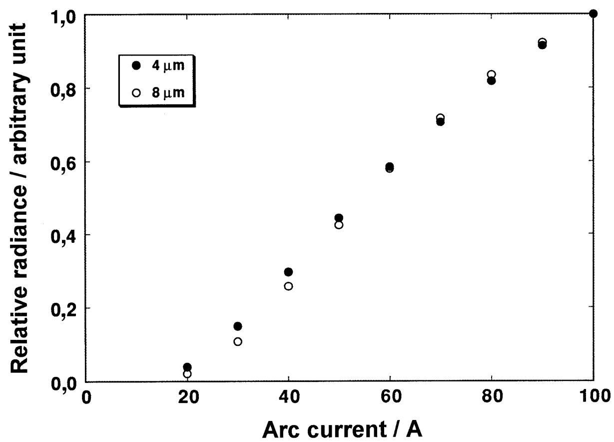

Figure 6. Relative arc radiance as a function of current, for 4 μm and 8 μm.

Figure 7 shows the variation in signal as the arc was translated across the optical path. These data represent the size and shape of the arc as a radiation source. For these measurements, a 0,6 mm entrance aperture and an f/17 optical beam were used. Data were taken at 40 A and 90 A for a wavelength of 4 μm, and at 90 A for 8 μm. The size and shape of the arc at these wavelengths are similar to those in the UV [1]. The spatial scan across the arc is approximately parabolic in shape, with a half-width of 2,5 mm. The arc appears to be somewhat broader at 90 A and 4 μm than it is in the other two cases.

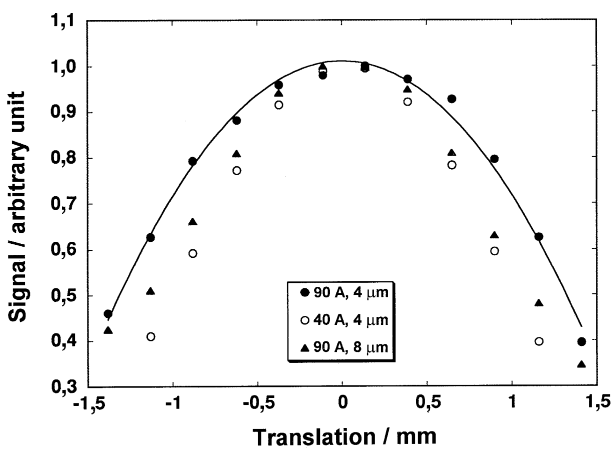

Figure 7. Relative arc radiance as a function of distance from arc axis. Observed area of arc was a 0,6 mm diameter circle. The solid line is a parabolic fit to the 90 A, 4 μm data.

6. Summary

A wall-stabilized argon arc source was shown to be a useful source for radiometry from 1 μm to 10 μm, due to its high radiance in this region. The spectrum below

3 μm is dominated by line emission. Beyond 3 μm, a calibration with 1 % spectral resolution showed the arc radiance to be comparable to that of black bodies at temperatures between 5000 K and 10 000 K. Plans for further work include extension to longer wavelengths of the higher-resolution scans as well as the radiance calibration. We will also measure the stability and reproducibility of the radiance and its dependence on ambient pressure.

Acknowledgement. The use of the argon arc as an infrared source was suggested by F. G. Sherrell, Sverdrup Technology, Inc.

References

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