measurement is that, for a symmetric film, the measurable A_y/A_x is identically 1 and the two other parameters, p and q, are equal. Thus, we are left with only two independent measurables for three unknowns. Therefore, a symmetrized measurement is excellent if one of the film parameters is known in advance, or if a second measurement is performed with a nonsymmetrized sample. The latter leads to the possibility of using 2-D graphical procedures. Such a procedure is demonstrated in Fig. 2, where the measurable parameters are plotted against each other with h/λ increasing along the curves. The parameter for the various curves is κ with n values restricted by Eq. (1), with the symmetrized Δ calculated for a film having parameters similar to those used in Ref. 1:

film thickness, $h = 1$ nm;
refractive index for the He–Ne laser wavelength (632.8 nm), $n = 3.35$;
absorption coefficient, $\kappa = 0.38$.

Unfortunately, here too the bunching for very thin films is evident. However this bunching is not the same for different sets of curves. For example, a number of n, κ, and h values may be derived if we use the Δ vs q curves. By using an additional set, such as the Δ vs A_y/A_x curves, a different range of values is obtained. The actual film parameters will lie in the intersection area of these two sets, reducing the number of possible solutions. Naturally, a further reduction of the ambiguity is obtained by using more such sets. Depending on the specific nature of the sample and the available equipment, further improvements are possible. The most promising of these are measurements with a number of wavelengths and measurements with a number of different refractive-index liquids.

The following numerical analysis was performed in order to evaluate all the proposed improvements: assuming the above mentioned sample, the measurable parameters were calculated for all the possible methods discussed. Each measurable parameter obtained was treated as an experimental outcome after an experimental error of 1% was assigned to it. The computer scanned the parameters in the following regions:

$$h = 0 \div 5 \text{ nm}, \quad n = 1.8 \div 4.5, \quad \kappa = 0 \div 0.45.$$

Because we deal here with a very thin film, the usual procedure led to ambiguous results. An almost continuous set of parameters was obtained, all of them in correspondence with the measured values within the assigned experimental error. These parameters were within the following ranges:

$$h = 0.6 \div 5.0 \text{ nm}, \quad n = 4.39 \div 1.91, \quad \kappa = 0.4 \div 0.24.$$

This result is in agreement with Ref. 1. It should be noted that large n values correspond to low h values; thus if some preliminary knowledge is available, such as by a different type of measurement, these ranges may be reduced.

An appreciable reduction of the ambiguity was achieved by adding a symmetrized measurement and using Eq. (1). For this type of calculation, the computer scan yielded the following range of solutions:

$$h = 0.8 \div 1.5 \text{ nm}, \quad n = 3.67 \div 2.86, \quad \kappa = 0.39 \div 0.34.$$

Naturally, more measurements will further reduce the range of solutions, for example, measurements with different refractive-index media in front of the sample or measurements with different wavelengths.

Analysis with a number of wavelengths was found to be the best solution. The measurement can be performed by a number of laser lines (in most cases two are adequate). Unfortunately such a procedure cannot ignore dispersion. To combine the measurements with different wavelengths correctly, an appropriate dependence of the parameters on wavelength should be taken into account. In our numerical analysis we assumed the Cauchi relation in order to calculate the measured values, but in the computer scan we required correspondence only for the thickness as measured by different wavelengths. Taking the He–Ne laser line together with one Ar laser line (488 nm) yielded the following three discrete solutions:

$h = 0.8$ nm,	1.0 nm,	1.3 nm,
$n = 3.67$,	3.35,	3.12,
$\kappa = 0.39$,	0.38,	0.36.

Restriction to a specific dispersion relation could eliminate the two incorrect results.

Considering the unusual characteristics of this film, this is a quite good result. However one must keep in mind that the actual experimental procedure is quite complicated, since it involves also a symmetrized sample measurement.

In conclusion it should be noted that all the difficulties discussed in this Letter apply only for extremely thin films on which no preliminary knowledge is available. It was shown that even for this extreme case, the novel method described in Refs. 2–4 can yield a consistent measurement without the help of any other measuring method.

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Lithium heat-pipe arc lamp

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Received 2 June 1980.
0003-6935/80/162660-02$00.50/0.

This Letter describes a lithium arc lamp of new design that is easy to construct and use as a laboratory source for spectroscopic investigations. Although low-pressure discharge lamps are commercially available for a large number of atomic species, there is no commonly used lithium discharge lamp.[1] Lithium lamps are difficult to construct because relatively high temperatures are required to achieve reasonable lithium vapor pressures, and because hot lithium vapor is highly corrosive and quickly attacks most window materials.

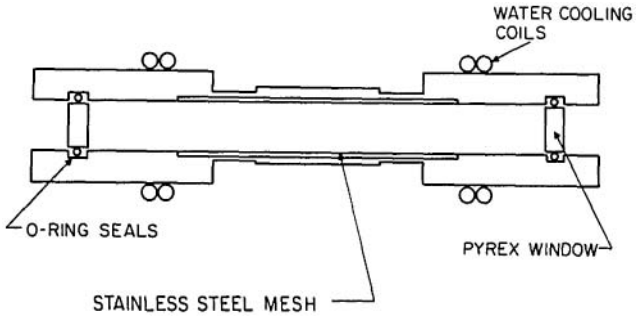

Fig. 1. Cross section of the disk-shaped heat-pipe oven.

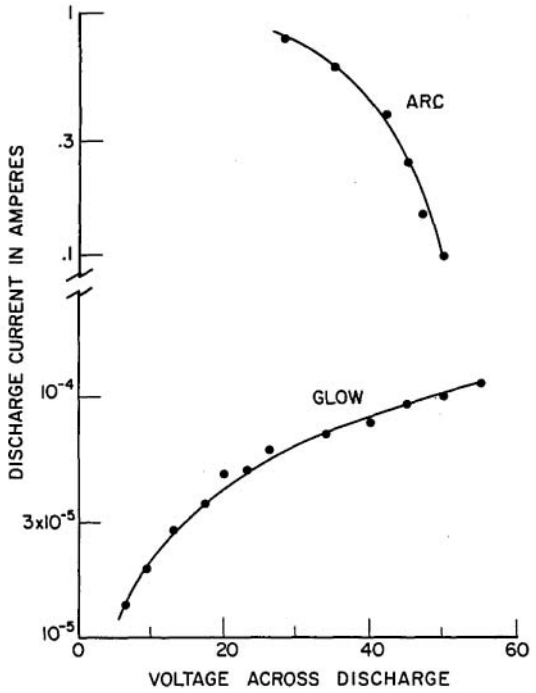

Fig. 2. Current–voltage characteristics of the lithium discharge lamp.

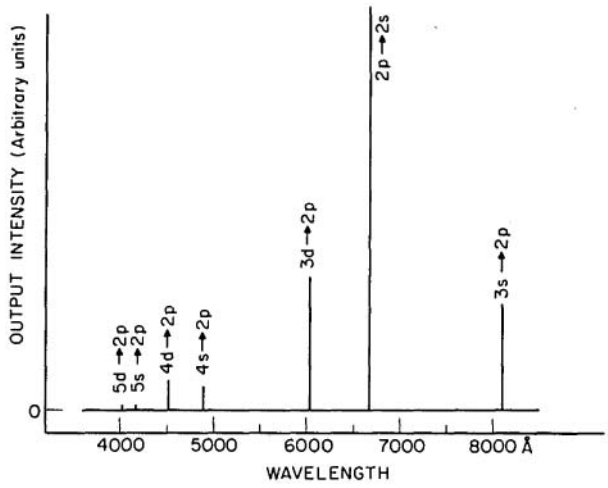

Fig. 3. Spectrum of light from the lithium arc lamp operating at 0.8-Å current.

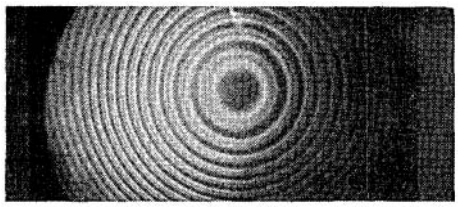

Fig. 4. Fabry-Perot interferogram showing the 0.34-cm^{-1} fine-structure splitting of the 6104-Å $3d \rightarrow 2p$ transition in lithium. Free-spectral range is 0.9 cm^{-1}.

We have circumvented these problems by containing a lithium vapor in the central region of a heat-pipe oven[2] of disk-shaped geometry[3] that allows large angular viewing of the discharge. The vapor is confined between two stainless steel plates as shown in Fig. 1 and is held in pressure equilibrium with a 1-Torr argon buffer gas that serves to isolate the hot lithium vapor from the cylindrical cell window. The plates are heated with propane–air torches to 750°C, at which temperature the lithium vapor pressure is equal to that of the buffer gas.

A discharge is established in the vapor by using the plates as electrodes and applying a voltage across them from a ballasted dc power supply. For currents in the 10^{-5}–10^{-4}-A range, a glow discharge is established; for currents >0.1 A, an arc discharge is established. The discharge current changes discontinuously between these two ranges, giving rise to the break in the current–voltage relation of Fig. 2.

We have determined the maximum radiance of the arc to be 14 mW/cm^2 sr by forming an image of the brightest part of the arc on a small aperture in a screen and measuring the flux transmitted into a small solid angle. We have also estimated the total radiant flux from the arc to be 13 mW from the measured value of the flux hitting a silicon photodiode of known area placed a known distance from the lamp. The light emitted by the lamp is quite red in appearance because of the predominance of the 6104- and 6708-Å lines in its spectrum, as shown in Fig. 3.

This lamp design should prove useful in producing discharges in other corrosive or refractory materials. Since it is quite practical to clean the interior of the lamp and refill it with a different atomic species, a single lamp can be used to produce several atomic spectra.

To illustrate the use of this lamp as a light source for spectroscopic calibrations, we have used it to measure the previously known fine-structure splitting of the 6104-Å $3d \rightarrow 2p$ transition in lithium. This splitting of 0.13 Å or 0.34 cm^{-1} is barely resolved in the presence of the 0.13-cm^{-1} Doppler breadth (FWHM) of the transition. This fine-structure splitting is shown resolved in the Fabry-Perot interferogram of Fig. 4, taken with a finesse of 20 and a free-spectral range of 0.9 cm^{-1}.

This work was partially supported by NSF grants SER77-06914 and ENG79-08038.

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Average similarities of Fourier spectra

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Received 27 March 1980.
0003-6935/80/162661-03$00.50/0.

A hybrid computation that combines optical and digital processing has attractive possibilities for such demanding applications as the classification of biological specimens. A hybrid system combines the parallel processing capabilities of a coherent optical system with the computational accuracy