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# NOTES AND DISCUSSION

## Inexpensive Rubidium-$D_2$ Filter

A. H. Firester
*RCA Laboratories, Princeton, New Jersey*
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Optical-pumping experiments are particularly suited for use in an advanced undergraduate or first-year graduate laboratory course.[1–3] One can easily demonstrate the magnetic-field dependence of the magnetic-dipole precessional frequency, the Zeeman effect, exchange polarization, as well as many other effects.[4] One of the very attractive aspects is the ease and simplicity with which the apparatus can be constructed.[1–3] Most of the apparatus can be fabricated by the student himself. The only expensive item is the interference filter, which transmits the $D_1$-resonance radiation and rejects the $D_2$-resonance radiation. An appropriate interference filter, a few inches square, although available commercially, typically costs a few hundred dollars.

It was recently pointed out[5] that this filtering can be done inexpensively and without a large loss in the signal-to-noise ratio by using the optical-pumping cell as a filter to absorb preferentially the $D_2$ radiation. Under some circumstances, a filter which would remove the $D_1$ radiation would be desirable for heuristic, as well as experimental, applications. In optical-pumping experiments, when a population difference between the two magnetic-field insensitive hyperfine sublevels is required, such a filter is quite useful.[6,7] For example, by pumping $^{87}$Rb vapor in the absence of a buffer gas (no excited state mixing) with $\pi$-polarized $D_2$ radiation, a population difference between the two $m_F = 0$ ground-state hyperfine sublevels will be formed.[7] This population difference could be detected in the direct beam using light-beat techniques[8] or by using a probing beam which had been prefiltered. This prefiltering can be done by passing the light through an absorption cell, thus, preferentially absorbing the resonance radiation from the upper[9,10] hyperfine sublevel. The range of experiments that can be done with a typical optical-pumping apparatus is thus extended by the availability of a $D_2$-transmitting filter. It is the purpose of this note to point out that such a filter can be constructed economically (less than $10).

It has been known for some time that a solution of neodymium chloride will suppress the $D_1$-resonance radiation of rubidium to the extent that it will not readily excite Raman shifts.[11] Such a solution will also adequately serve as a $D_1$-rejection filter in a rubidium optical-pumping apparatus. A 1-cm thickness of a 0.4 *M* solution of neodymium chloride transmits 60% of the rubidium-$D_2$ radiation (7800 Å) while rejecting over 99% of the rubidium-$D_1$ radiation (7948 Å). Figure 1 shows the transmission of such solutions from 7775 Å to 8000 Å. Thus, by simply constructing a suitable cell and filling it with a solution of neodymium chloride,[12] a rather effective filter can be constructed. Such a filter could be made as large as desired and would not suffer from the angular restrictions common to interference filters.[13]

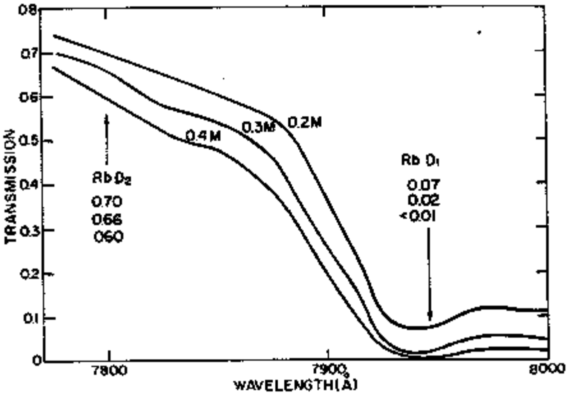


Fig. 1. The transmission characteristics of a 1-cm thickness of neodymium chloride solution of 0.2*M*, 0.3*M*, and 0.4*M*, concentration.

Thus, this filter serves as an easily and inexpensively constructed accessory to be used with a rubidium optical-pumping apparatus. Since the optical properties of the filter can be changed continuously, the student builder can see the effects of various $D_1/D_2$ ratios, thereby augmenting still further the experimental capabilities of the optical-pumping apparatus.


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## Note on Elastic Scattering

J. Olsen
*Danish Atomic Energy Commission, Research Establishment Risö, Roskilde, Denmark*
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In a recent note in this Journal[1] it was proved that the frequency of a Compton-scattered gamma ray is given by the formula for the Doppler effect and that the scattering angle plus the angle of incidence can be expressed by the formula for the aberration.

It is the purpose of the present note to show how these equations can be derived by means of the simple kinematic relation of two-particle scattering in the center-of-mass system.