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REFRACTIVE INDEX OF CARBON TETRAFLUORIDE (CF_4) IN THE 300-140 nm WAVELENGTH RANGE

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The refractive index of carbon tetrafluoride (CF_4) has been measured by Fabry-Perot interferometry down to 140 nm.

1. Introduction

Discriminating particles with nearly equal mass in high-energy beams requires highly performing Cherenkov detectors. Since Cherenkov light is emitted with a spectrum varying as λ^{-2}, therefore yielding most of the photons in VUV and beyond, experimentalists have long been looking for the ideal gas radiator, transparent in VUV and having a chromatic dispersion low enough to prevent chromatism correction and if possible a fairly high index value at atmospheric pressure. The least dispersive gas known so far was helium, but $n - 1 = 35 \times 10^{-6}$ only. Recently, carbon tetrafluoride (CF_4) was thought to show even higher performances than helium around 150 nm. The values of refractive index obtained by Watson and Ramaswamy [1] in visible, and the values obtained by a first-order extrapolation from index measurements on liquid CF_4 at wavelengths down to 180 nm by Seguinot [2], seemed to be very encouraging. Using a TEA (triethylamine)-CH_4 mixture in the photon detector, to allow only a 20 nm acceptance width around 150 nm, could save building an expensive and uncertain achromatisation device while a fair amount of photons could be still recorded. The WA89 experiment at CERN is planning to use a RICH (ring imaging Cherenkov) detector for discriminating Ξ^- and Σ^- hyperons in a 270 GeV/c beam. This has prompted us to make precise measurements of the index on the gas itself down to 140 nm.

2. Experimental setup

The measurements have been performed with a Fabry-Perot (FP) interferometer, according to an experimental technique previously described [3,4]. The interferometer has magnesium fluoride plates coated with a double layer of Al + MgF_2. Its performance has been described elsewhere [5]. The light source was either a platinum hollow-cathode lamp with a magnesium fluoride window or a lead hollow-cathode one with a quartz window. The pressure in the FP cavity was measured by a Hg manometer with a total 0.05 mm accuracy, and the temperature near 290 K was determined by means of a thermocouple to about 0.05 K. Two spacers of 1.8 and 2.9 mm were used, and the thickness was accurately measured by a coincidence method. The errors on pressure, temperature and spacers' thickness were weak compared with the error produced by measurement of the fractional part of the fringes. We obtain an accuracy of one twentieth of a fringe over 10 to 15 fringes, depending on the wavelength and the spacer thickness, on an individual record of the fringes.

The statistical treatment of about twelve measurements for each wavelength allows us to estimate the accuracy on (n-1) to be better than 0.2%. However, this accuracy is not reached for the 140.4 nm wavelength because of the weakness of this spectral line, and it shall be estimated to about 1%.

3. Results and discussion

The refractive indices are given at standard temperature and pressure conditions (0°C and 760 mmHg) using the formula given by Badyl'kes [6]. Our experimental results are given in table 1. The first column gives the wavelengths of the measurement points; they are vacuum wavelengths. Our experimental results are given in the second column and correspond to $(n-1) \times 10^6$ values. The third column gives results from Watson and Ramaswamy [1]; in their paper the index is given at 25°C and 760 Torr, so in the table we give temperature-corrected results to allow comparison with our results.

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The comparison is made through a one-term Sellmeier formula, fitted by using their and our results. The Sellmeier results in the fifth column show a fairly good agreement with both results:

$$n-1=\frac{A\times 10^{-6}}{\lambda_0^{-2}-\lambda^{-2}},$$

where $\lambda_0^{-2}=2.61154\times 10^{-4}$ and $A=0.124523$, when the wavelengths are in nm units.

The other results obtained by Klemm and Henkel [7], given in the fourth column, show a small discrepancy of about 1% and they have not been used in the fitting of the Sellmeier expression.

$\lambda_0=61.88$ nm is a single wavelength representing the whole absorbing spectrum in the far UV. It is also known as the excitation potential by $E_0=20.04$ eV, which may be compared to the value of 19.7 eV published by Wemple [8]. The small discrepancy between the two values is meaningless because the excitation potential is far from our experimental wavelength range.

In fig. 1 we have plotted the different results. The solid line represents the interpolated values obtained from the Sellmeier formula.

Seguinot [2] gives a linear energy variation of the refractive index, using measurements in the region 180–250 nm (5–7 eV). This linearity can be explained by the narrowness of their experimental wavelength range but does not correspond to the Sellmeier-type variation law that we obtain.

Table 1
CF_4 refractivity expressed as $(n-1)\times 10^6$. Comparison with other results

Wavelength [nm]	Present work	Watson et al. [1]	Klemm et al. [7]	Sellmeier fitting
140.47	591.0			591.6
150.93	573.6			573.2
152.47	571.1			570.8
167.15	552.1			552.5
182.20	538.5			539.0
206.82	523.6			523.7
244.08	510.0			509.6
280.28	500.8			501.2
435.95		486.7		486.6
480.12		484.9		484.9
508.72		484.05		484.0
546.23		483.1	487.5	483.0
587.7			486.5	482.3
643.99		481.2		481.2

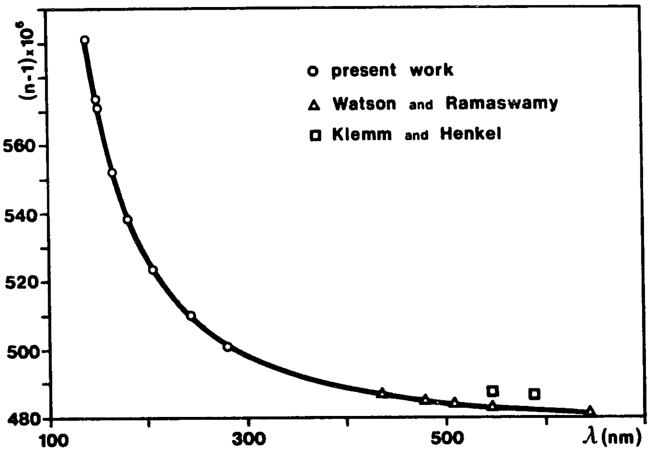

Fig. 1. The refractivity of CF_4 is plotted versus the wavelength. The solid line corresponds to the Sellmeier formula.

4. Conclusion

From the liquid-CF_4 measurement the Abbe number for 144, 150 and 155.6 nm was expected to be around 85, versus 53 for helium. The present results show that it should be rather taken as 31. It should therefore be considered that helium is still the best gas to be used as a radiator in Cherenkov detectors and that in many cases achromatisation devices cannot be avoided.

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