This article was downloaded by: [University of California, San Diego]

On: 22 August 2012, At: 09:25 Publisher: Taylor & Francis

Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH,

UK



Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information: http://www.tandfonline.com/loi/gmcl20

Determination of the Circular Polarized Fraction of Light using a Voltage Driven Nematic Liquid Crystal Wave-Plate

J. M. Daniels ^a

^a Advanced Liquid Crystal Technologies, Summit, NJ, USA

Version of record first published: 31 Jan 2007

To cite this article: J. M. Daniels (2005): Determination of the Circular Polarized Fraction of Light using a Voltage Driven Nematic Liquid Crystal Wave-Plate, Molecular Crystals and Liquid Crystals, 434:1, 231/[559]-233/[561]

To link to this article: http://dx.doi.org/10.1080/15421400590954849

PLEASE SCROLL DOWN FOR ARTICLE

Full terms and conditions of use: http://www.tandfonline.com/page/terms-and-conditions

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae, and drug doses should be independently verified with primary sources. The publisher shall not be liable

for any loss, actions, claims, proceedings, demand, or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.

Mol. Cryst. Liq. Cryst., Vol. 434, pp. 231/[559]-233/[561], 2005

Copyright © Taylor & Francis Inc. ISSN: 1542-1406 print/1563-5287 online DOI: 10.1080/15421400590954849



Determination of the Circular Polarized Fraction of Light using a Voltage Driven Nematic Liquid Crystal Wave-Plate

J. M. Daniels

Advanced Liquid Crystal Technologies, Summit, NJ, USA

We present a two measurement method to extract the circularly polarized fraction of light at a particular wavelength. It involves a voltage driven nematic liquid crystal wave-plate and a polarizing filter oriented with their axes 45° to each other. The circular polarized component is calculated from intensities transmitted when the liquid crystal wave-plate acts as a 1/4 wave-plate at one voltage and 3/4-wave plate at another.

Keywords: circular polarized light; nematic liquid crystal wave-plates

Evidence for the usefulness of Helium-3 gas as an enhancer for lung MRI continues to grow [1]. The goal of our research is to help promote the use of Helium-3 (³He) in enhanced lung MRIs by constructing a portable, fully automated machine to polarize Helium-3 gas. Here we present an example where the remarkable electro-optic properties of nematic liquid crystals help miniaturize and automate a process that currently requires several square meters of lab space and the attention of several highly skilled personnel.

We use a density matrix [2] description of the polarized states of light. This is a more general description than needed for liquid crystal device optics. We like it because it accesses analytic tools, techniques and measurement theory developed for Quantum Mechanics [2] (that can be related to parameters used in older phenomenological descriptions of polarized light) and can be extended to quantify (for example) the director orientation (optic axis) of the beautiful micrographs used to analyze liquid crystalline order.

We thank P. E. Cladis and E. Y. Chen for stimulating discussions and Philip Morris USA and the National Institutes of Health for partial support of this work.

Address correspondence to J. M. Daniels, Advanced Liquid Crystals Technologies, PO Box 1314, Summit, NJ 07902-1314, USA. E-mail: daniels@alct.com

To polarize (magnetize) ³He, we use the classical MEOP (metastability exchange and optical pumping) method. In MEOP, a weak electrodeless discharge at a pressure of 1 torr creates a ³He plasma that is irradiated with circular polarized light (1083 nm) directed along a weak magnetic guide field [3], **H** in Figure 1.

The polarization, \mathbf{P} , of ³He in this gas can be determined by measuring the circular polarized fraction of 668 nm light emitted by the plasma in the direction of the magnetic field [4]. A device to determine the fraction of polarized light during the MEOP process cannot have moving parts (to avoid magnetic fields that will disturb the guide field, \mathbf{H}) and must be insensitive to the pumping radiation (1083 nm) which is also along \mathbf{H} (Fig. 1).

The method we propose is the following. Measure the intensity of the 668 nm light emitted by the plasma e.g. with a photodetector, after is has passed first through a liquid crystal wave-plate then a polarizing filter (e.g. a Polaroid) (Fig. 2).

Set the fast axis (F) of the wave-plate at an angle θ to the reference direction x. The direction of the **E** vector passed by the polarizing filter is set at an angle ψ to x. Voltages are applied so that the retardance of the wave-plate can be either $\lambda/4$ or $3\lambda/4$.

In the analysis, we represent the state of polarization in photon spin space by a 2×2 density matrix, ρ , with elements: $\rho_{11}=a+b$ and $\rho_{22}=a-b$ while $\rho_{12}=c-id$ is the complex conjugate of $\rho_{21}=c+id$: $i^2=-1$ and the axis of quantization is the direction of propagation.

Elements of the density matrix, ρ , are related to the phenomenological Stokes parameters as:

$$a=I/2,\ b=V/2,\ c=-Q/2,\ d=U/2.$$

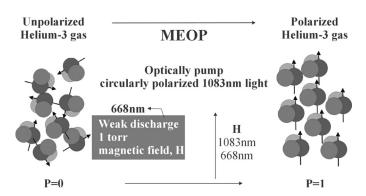


FIGURE 1 Schematic for the MEOP method to polarize Helium-3 gas.

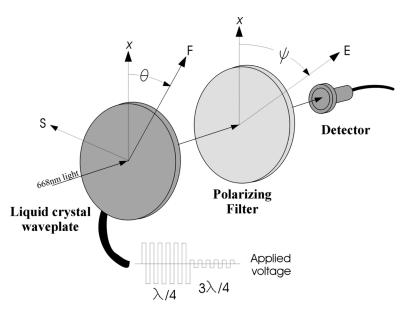


FIGURE 2 Set-up to measure the circularly polarized fraction of 668 nm light emitted by the Helium-3 plasma.

When the wave-plate is set to be a $\lambda/4$ plate, the transmitted intensity is $I_1\colon$

$$I_1 = a - b \sin(2\psi - 2\theta) - (c \cos 2\theta + d \sin 2\theta) \cos(2\psi - 2\theta).$$

When the wave-plate is set to be a $3\lambda/4$ plate, the transmitted intensity is $I_2\colon$

$$I_2 = a + b \, \sin(2\psi - 2\theta) - (c \, \cos\!2\theta + d \, \sin\!2\theta) \, \cos(2\psi - 2\theta).$$

Choose θ to have any value, and $\psi = \theta + 45^{\circ}$. Then:

$$I_1 = \mathbf{a} - \mathbf{b}$$
 and $I_2 = \mathbf{a} + \mathbf{b}$.

Thus, the fraction of circularly polarized light is $(I_2-I_1)/(I_2+I_1)$.

REFERENCES

- Eberle, B., Markstaller, K., Schreiber, W. G., & Kauczor, H.-U. (2001). Swiss. Med. Weekly, 131, 503.
- [2] Landau, L. D. & Lifshitz, E. M. (1963). Quantum Mechanics, Non-relativistic Theory, Second Revised Edition, Pergamon Press: New York, 38.
- [3] Colegrove, F. D., Schearer, L. D., & Walters, G. K. (1963). Phys. Rev., 132, 2561.
- [4] Pinard, M. & van der Linde, J. (1974). Canad. J. Phys., 52, 1615.