Technical Information · Optical Glass
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Faraday effect in optical glasses. The wavelength dependence of the Verdet constant.

When linearly-polarized electromagnetic radiation passes through an optical, otherwise non-active medium in parallel with the direction of a magnetic field, the plane of vibration of this radiation is rotated (Faraday effect). We know from experiments that the angle of rotation α is proportional to the path length l through the medium and to the absolute value B of the magnetic induction flux density as long as B is sufficiently small.

$$\alpha = V \cdot B \cdot l \qquad (1)$$

The constant of proportionality V is called Verdet constant.
It is a material-specific quantity and depends on the wavelength λ of the electromagnetic radiation. With the direction of the magnetic field parallel or antiparallel to that of the propagation of the electromagnetic wave within the medium, one can observe the plane of vibration rotating clockwise or counterclockwise, corresponding to positive or negative values of α.
In the present Technical Information we have adopted the definition used in recent scientific literature.
Thereafter, the values of α and V are positive if the plane of vibration rotates clockwise looking parallel to the vector $\vec{B}$ of the induction flux density irrespective of the propagation of the wave being parallel or antiparallel to $\vec{B}$.
Positive values can be observed for all diamagnetic and some paramagnetic glasses.
If, on the same premises, the plane of vibration is rotated counterclockwise, V has a negative value. This can be observed in the case of some paramagnetic glasses.

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TECHNICAL INFORMATION TI No. 11, SCHOTT Optical Glass (May 1976), included the Verdet constants of 9 optical glasses for different wavelengths.

In the table following this text, we give new experimental data of the Verdet constants V of 39 glasses at 20 °C for different wavelengths λ, the unit of V being rad/T·m. The error of measurement is 4 % of the respective V value plus 0.5 rad/T·m.

Optical glasses SF 59, SF 58, SF 57 and SF 6 possess the largest Verdet constants in that table. On the other hand, glasses SF L 6 and SF L 56, for example, have extremely small Verdet constants.

In order to describe V as a function of wavelength the dispersion equation

$$V(\lambda) = \frac{\pi}{\lambda} \frac{n^2(\lambda) - 1}{n(\lambda)} \left(A + \frac{B}{\lambda^2 - \lambda_0^2}\right) \qquad (2)$$

has been developed. The fitting parameters A and B for V(λ) and the mean wavelength λ_0 of the UV resonances are also given in the table. The refractive indices n(λ) to be inserted into (2) are given in SCHOTT catalogue No. 3111, "Optical Glass", or can be calculated from the dispersion equation there included.

The data of the Verdet constant can be extrapolated up to a wavelength of λ = 1060 nm, using equation (2). The experimental values as well as the fitted curves of functions V(λ) are shown in figures 1 to 3 for the glass types mentioned. Using dispersion fomula (2) for V(λ), the mean relative error R_{rel} is calculated from

$$R_{rel} = \frac{1}{m} \sum_{i=1}^{m} \left| \frac{V_{exp}(\lambda_i) - V(\lambda_i)}{V_{exp}(\lambda_i)} \right| \qquad (3)$$

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where $V_{exp}(\lambda_i)$ and $V(\lambda_i)$ are the experimental data and the values according to equation (2) for wavelength λ_i respectively; m is the number of the different wavelengths λ_i.

In all cases, the mean deviation of the experimental data points from the fitting curves is less than the experimental uncertainty as can be seen from the last row in the table.

Becquerel's formula, which has been used in TI No. 11 in order to describe the wavelength dependence of the Verdet constant $V(\lambda)$ provides a fit to the measured data which is in general somewhat less accurate.

Figure 1 shows the data of glasses with the largest and smallest values of $V(\lambda)$. Glasses with intermediate values are represented in figures 2 and 3 at different scales.

For glasses SF L 56 and SF L 6, a fit according to equation (2) is not possible, as the measured data are of the order of the absolute error.

The data for glass SF L 6 have not been plotted, since the measured values are close to zero.

Use of Faraday effect

The rotation of the plane of vibration or the optical activity as a result of circular birefrigence of the glasses within a magnetic field may be utilized with the aid of polarizers for fast optical shutters. A light beam can be switched on and off or can be modulated by a magnetic field with very high frequency.

In laser engineering, Faraday glasses are also employed as "one-way streets for light", since monochromatic electromagnetic waves can be transmitted by an appropriate combination of polarizers with such glasses within a magnetic field in one direction only.

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Verdet constant V(λ) of different optical glasses and fitting parameters A and B for the application of equation (2)

Glass type	V(λ) [rad/T · m]						λ_0 (nm)	A (10^{-7} rad/T)	B (10^{-19} rad m^2/T)	Rrel (%)
	439.5 (nm)	480.0 (nm)	546.1 (nm)	589.3 (nm)	632.8 (nm)	656.3 (nm)				
FK 3	7,6	7,6	5,5	4,9	4,1	3,5	95,3	7,2702	1,3333	6,6
FK 5	8,4	7,0	5,5	4,7	4,7	3,8	92,3	7,3531	1,2647	3,2
FK 51	7,1	6,1	4,7	4,1	3,5	3,2	84,7	5,4805	1,2695	1,6
FK 52	7,6	6,4	4,9	3,8	3,2	3,2	86,2	4,1070	1,6842	3,7
PK 2	9,3	8,4	6,4	5,2	4,7	4,4	96,4	7,1672	1,5350	2,9
BK 3	9,0	7,6	6,1	4,9	4,4	4,1	96,1	6,8316	1,5282	1,8
BK 7	10,5	8,7	6,4	5,2	4,9	4,1	97,0	5,5387	2,1116	3,1
BaLK N 3	11,3	9,3	7,0	5,8	5,2	4,4	100,0	5,9938	2,2601	2,4
K 3	-	9,6	7,3	6,1	5,2	4,7	101,0	1,2978	3,8205	7,1
BaK 50	12,2	9,9	7,9	6,7	5,8	4,9	102,6	7,2536	1,9887	2,9
SK 16	12,5	10,2	7,6	6,4	5,5	4,9	101,2	5,5302	2,1438	1,0
SSK N 5	11,3	10,2	7,6	6,7	5,8	5,0	110,6	8,3749	1,2103	2,5
LaK N 12	13,1	11,1	8,5	7,3	6,1	5,5	106,5	6,7875	1,8439	2,2
LaK N 14	9,5	8,7	6,7	5,5	4,9	4,7	106,5	6,4470	1,0542	3,0
LF 3	20,1	16,3	11,9	10,2	8,4	8,1	120,4	9,4425	3,4867	1,1
F 2	25,3	20,1	15,1	12,5	10,8	9,9	129,7	11,1061	4,0872	0,6
F N 11	-	3,5	3,5	2,6	2,6	2,6	130,1	1,2158	1,2041	16,7
F 13	25,9	20,7	15,4	12,8	10,8	9,9	130,4	10,6164	4,3176	1,0
LaSF N 31	9,6	9,3	7,3	6,4	5,5	5,2	125,4	7,0445	0,5728	3,8
LaSF 32	-	3,8	3,2	2,9	2,6	2,6	143,9	0,9594	0,9845	15,3
SF 1	37,8	30,0	21,5	18,0	15,4	14,5	144,7	13,4192	5,4231	0,6
SF 2	31,0	23,0	16,9	13,8	11,6	9,9	134,6	7,0169	5,7546	2,5
SF 5	31,7	25,6	18,6	15,7	13,1	11,9	138,2	11,9072	4,9469	1,3
SF 6	49,5	39,3	28,5	23,6	20,1	18,3	156,4	15,7116	6,3430	0,6
SF L 6	-	-1,2	0-	0,0	0+	-	156,6			
SF 8	33,3	26,5	19,8	16,6	14,3	13,1	140,5	14,0098	4,6893	0,5
SF 14	36,7	29,1	21,2	17,7	15,1	13,4	152,8	12,3008	4,9536	1,3
SF 18	39,3	30,3	22,1	18,6	15,7	14,0	145,2	12,2097	5,8514	1,2
SF 53	38,7	29,7	21,5	17,7	15,1	13,7	146,7	11,0378	5,8444	0,7
SF L 56	-	-0,6	0,0	0,3	0,3	-	154,3			
SF 57	55,0	44,2	31,7	26,2	21,8	20,7	161,7	16,7417	6,7168	1,1
SF 58	67,5	54,7	39,0	31,7	27,1	23,9	170,5	18,2033	7,7697	1,8
SF 59	68,8	57,0	41,3	33,5	28,5	27,1	175,3	22,6382	6,8410	1,9
SF N 64	-	1,2	1,5	1,2	1,5	1,2	142,8	0,7433	37,1043	26,5
TiK 1	9,9	8,4	6,7	5,5	4,7	5,2	100,8	9,1198	1,4464	4,2
TiF 3	4,1	3,8	3,8	3,2	2,3	2,6	119,9	5,9402	0,0959	7,6
TiF 6	-	3,2	2,6	2,3	2,3	2,0	140,6	0,9432	1,0387	14,7
KzFS N 4	18,0	14,3	11,1	9,3	7,9	7,3	117,8	8,7691	2,8597	1,4
LgSK 2	12,2	9,9	8,1	7,0	6,1	5,2	100,6	8,2800	1,7067	3,1

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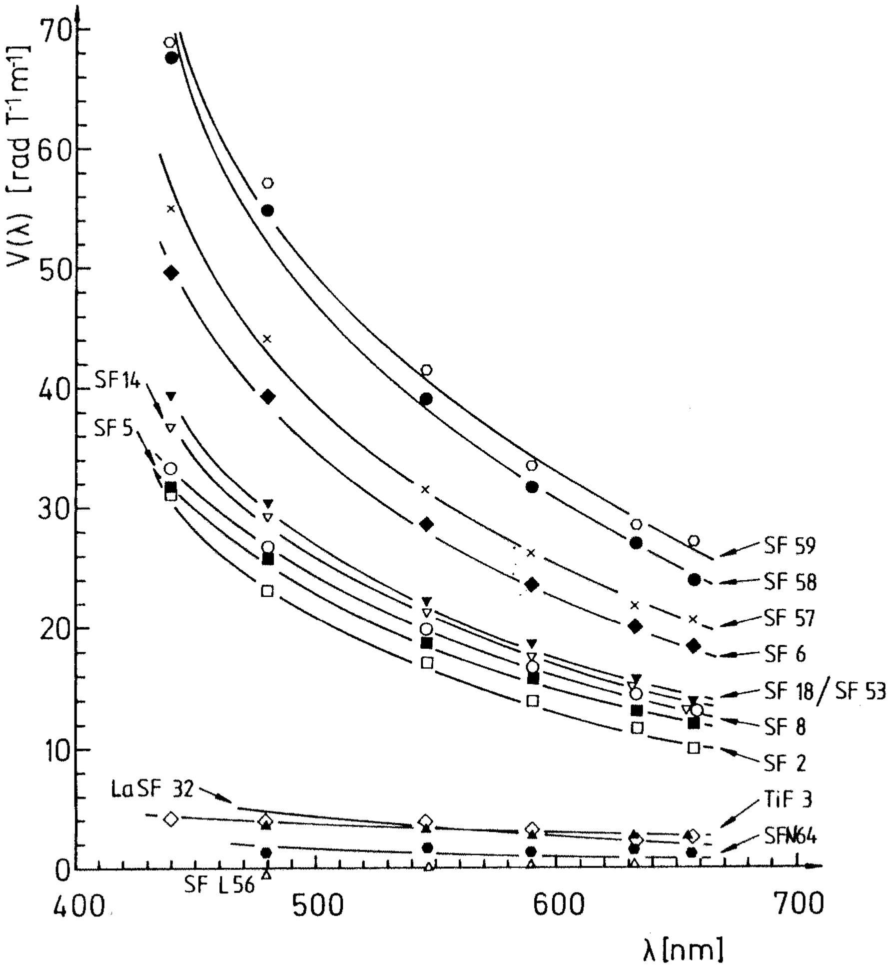

Fig. 1 Verdet constant V of some optical glasses as a function of wavelength λ.

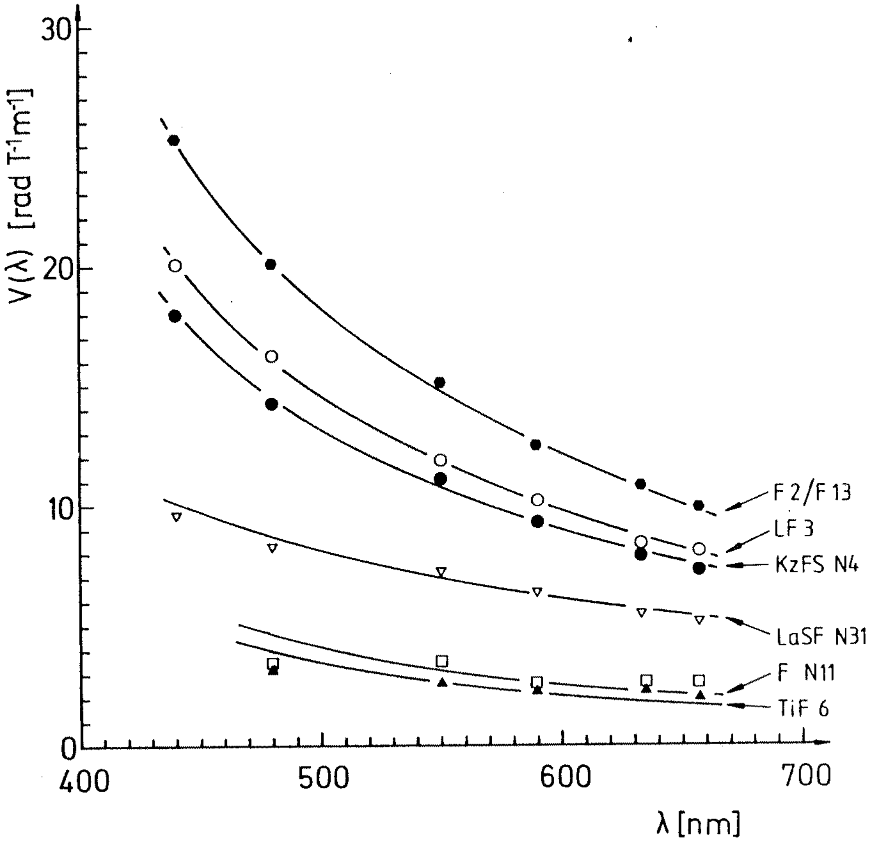

Fig. 2 Verdet constant V of some optical glasses as a function of wavelength λ.

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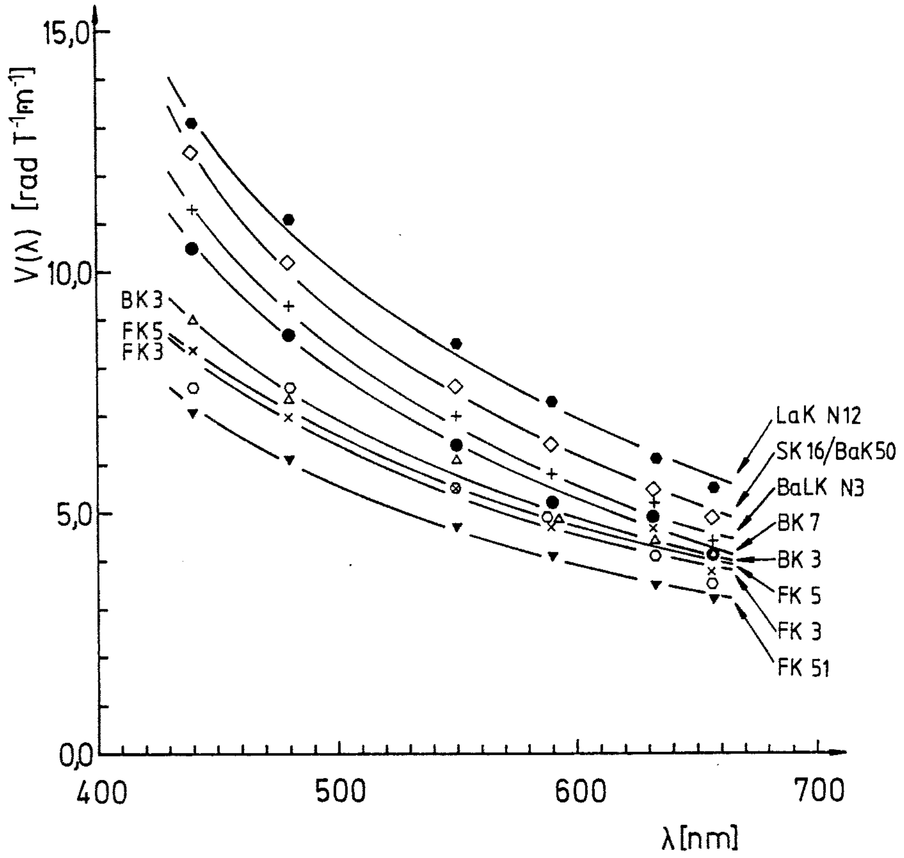

Fig. 3 Verdet constant V of some optical glasses as a function of wavelength λ.