On the efficiency of backward collinear acousto-optic interaction between terahertz radiation and acoustic beam in hexane

Nikitin Pavel A.[1,2]

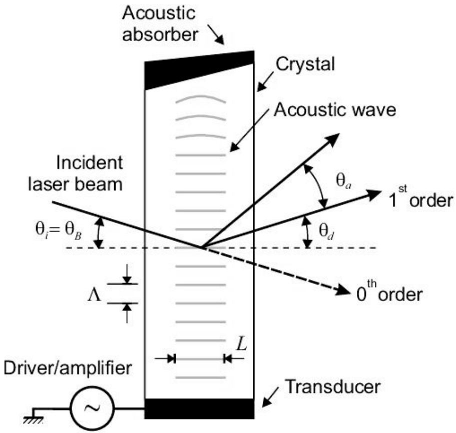
[1]Scientific and Technological Center of Unique Instrumentation of RAS

[2]Lomonosov Moscow State University

Synchrotron and Free electron laser Radiation: generation and application (SFR-2020)

Acousto-optic interaction

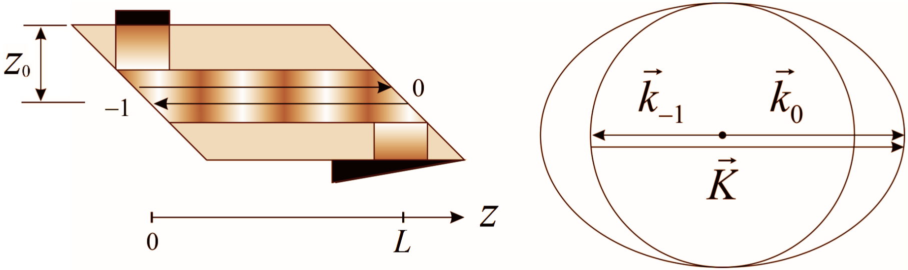
Basic principals



$$\frac{I_1}{I_0} \propto \frac{1}{\lambda^2} \cdot \exp(-\alpha L) \cdot M_2 \cdot P_a$$

Backward collinear AO interaction

Scheme and wave-vector diagram



- Under thes regime, the highest spectral resolution can be achieved
- Sound with ultrahigh frequencies should be used:
  $F \approx 1$ GHz at $\lambda \approx 1$ μm and $F \approx 10$ MHz at $\lambda \approx 100$ μm
  $F = 2 \cdot n \cdot V/\lambda$
- The distance z_0 from sound transducer to input optical window is about several centimeters

Backward collinear AO interaction

Hexane as the best medium of AO interaction

15th International Conference on Optical Methods of Flow Investigation 2019 IOP Publishing
Journal of Physics: Conference Series **1421** (2019) 012032 doi:10.1088/1742-6596/1421/1/012032

A review of non-polar liquids as materials for bulk acousto-optic devices operating with terahertz radiation

P Nikitin[1,2]

Table 1. Acoustical, optical and acousto-optical properties of selected liquids.

liquid	ρ (g/cm^3)	V (km/s)	$\alpha_s/(2F^2)$ (10^{-17} s^2/cm)	n	α (cm^{-1})	M_2 (10^{-15} s^3/kg)
C_6H_{14}	0.655	1.077	60	1.372	0.69	847

Table 3. Properties of acousto-optic filters based on liquids.

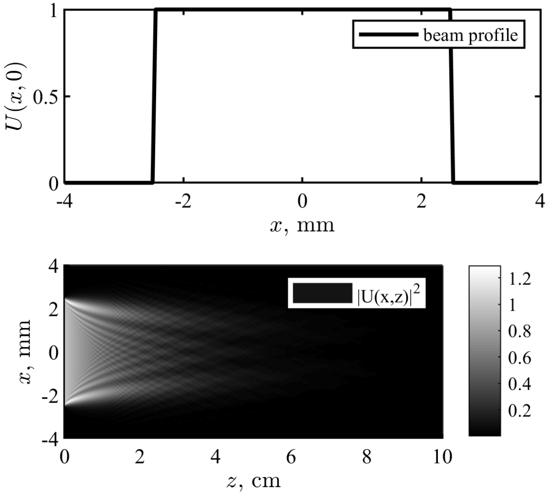
liquid	F (MHz)	α_s (cm^{-1})	I_{-1}/I_0, (10^{-4})	R (10^3)
C_6H_{14}	21.1	0.5	9.3	0.6

$$\frac{I_{-1}(0)}{I_0(0)} = \frac{\pi^2}{2\lambda^2}\frac{M_2 P_a}{S}\left(\alpha + \frac{\alpha_s}{2}\right)^{-2}$$

$$R = \frac{k}{\Delta k} = \frac{2\pi n}{\lambda}\frac{1}{\alpha + \alpha_s/2}$$

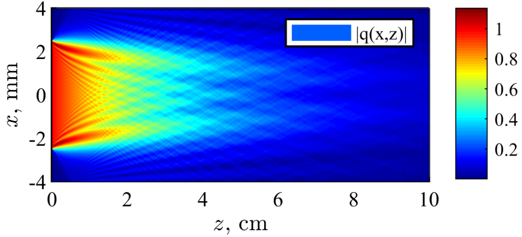
Sound beam modelling

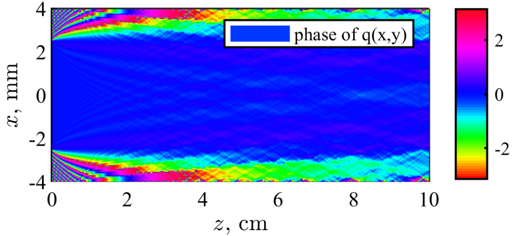
Method - Fourier transform (PZT - 5x5 mm)



Sound beam modelling

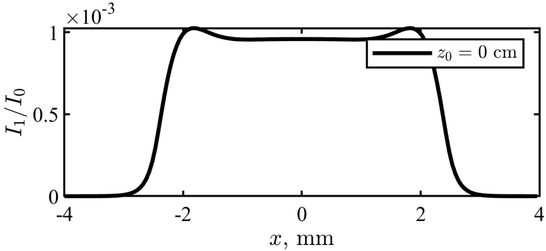
AO coupling coefficient





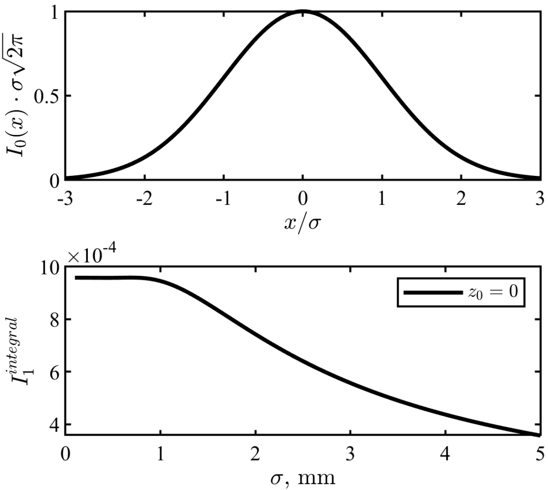
AO diffraction

Infinite light beam ($\lambda = 130\ \mu m$, $z_0 = 0\ cm$)



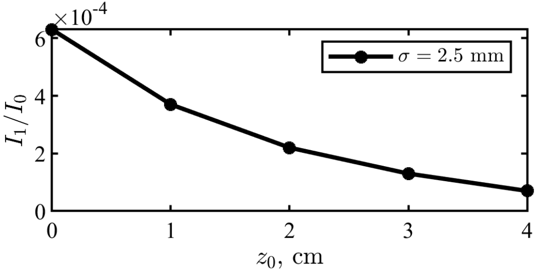
AO diffraction

Gaussian light beam ($\lambda = 130\ \mu m$, $z_0 = 0\ cm$)



AO diffraction

Gaussian light beam ($\lambda = 130\ \mu m$, $\sigma = 2.5\ cm$)



Conclusion

Conclusion

- Theory of 2D acousto-optic interaction was applied to the regime of backward collinear diffraction.
- The acoustic field in liquid was modelled by Fourier transform method.
- It was established that diffraction efficiency is the highest for narrow THz light beam ($\sigma < 1$ mm) (half THz beam diameter) and decreases as $1/\sigma$ at $\sigma > 1$ mm, as the light beam becomes wider than the sound beam.
- It was shown diffraction efficiency decreases with distance z_0 from piezo-electric transducer (PZT) to input optical window due to sound attenuation.

Acknowledgments

The results were obtained with support of the Russian Science Foundation (RSF) grant No.18-12-00430.

Any questions