High power terahertz wave emission using DAST crystal

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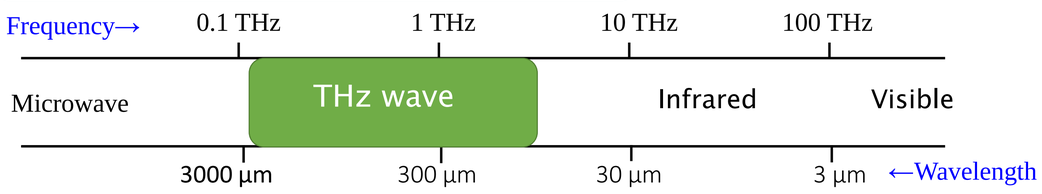
1.Background



Characteristics of Terahertz wave

- Transmits through various materials such as plastics, ceramic, fabrics etc.
- Strongly absorbed by water
- Relatively safe to human body
- Various drugs and explosives have spectral fingerprint in THz region

Applications of terahertz wave

- Homeland security
- Non-destructive testing and analysis
- Biomedical applications (skin cancer detection)
- High-speed data communication (post 5G / 6G communication)

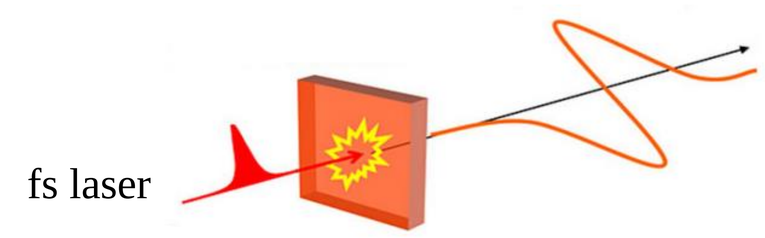
2.Objectives

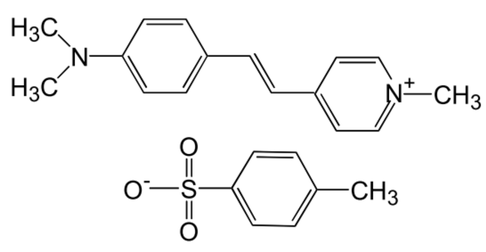
- The power of terahertz wave emitted by non-linear optical crystal via optical rectification of femto-second laser pulses depends upon the power of the laser used to pump the optical crystal.
- However, significant amount of pump power is lost due to Fresnel's reflection at air-crystal boundary during this process.
- In this study, we used the anti-reflection (AR) coat known as cytop on the surface of non-linear crystal 4-Dimethylamino-N-methyl-stilbazolium tosylate (DAST), which enabled to increase the incident pump power.
- The power of terahertz wave generated by DAST crystal with AR coating is higher than the power of terahertz wave generated by the crystal without AR coating.

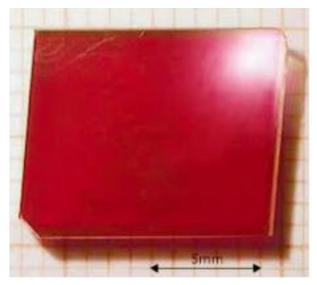
Importance of Anti-reflection coat in DAST crystal

High power and broadband THz wave is essential to further expand the applications of THz wave. In the past, there have been large numbers of reports on high power THz wave generation using different methods such as optical parametric generation, quantum cascade laser, laser plasma interaction. Among these methods, optical rectification of femtosecond pulses in non-linear optical crystal is one of the widely used methods to emit broadband and high-power terahertz waves. In this process, the power of terahertz wave is directly proportional to the square of the power of femtosecond pump laser. Therefore, high power terahertz wave can be generated using high power pump laser provided that the non-linear crystal has high damage threshold and high optical non-linear coefficient. Despite the fact that the high-power terahertz wave can be generated using such crystals, the efficiency of terahertz wave generation is limited by the loss of laser power due to Fresnel's reflection at the boundary between air and crystal. However, selection of appropriate anti-reflection coating with proper thickness help reduce the laser power reflection, thereby increasing the resultant incident pump power. In this study, we experimentally demonstrate that use of antireflection coat on the surface of optical crystal effectively reduces the reflection loss of pump laser, thereby increasing the incident laser power. This enables us to enhance the terahertz wave emitted by optical crystal with the anti-reflection coating.

*4-dimetylamino-N-methyl-4-stiibazolium tosylate…***DAST**







Crystal	CdTe	GaP	GaSe	ZnTe	LiNbO3	DAST
d_{ij}(pm/V)	d_{14}=168	d_{14}=220	d_{22}=54	d_{14}=90	d_{33}=34.1	d_{11}=1010
α(cm^{-1})	4.8	0.2	0.5	1.3	17	50
FOM	11	0.72	1.18	7.27	18.2	41.5

4.Numerical calculation

(a) Anti-reflection coat thickness calculation

At the normal incidence of light, the reflectance is written as

$$R = \left(\frac{n_{air}\, n_{crystal} - n_{film}^2}{n_{air}\, n_{crystal} + n_{film}^2} \right)^2$$

Where n_{air} is refractive index of air, $n_{crystal}$ is refractive index of crystal and n_{film} is the refractive index of the thin film. In order to make the value of R = 0, the numerator of the right term should be

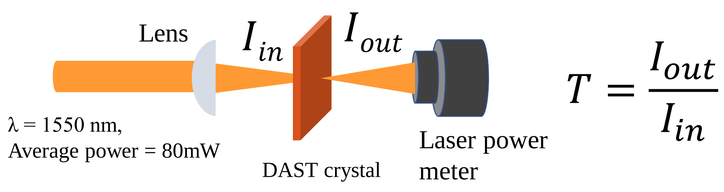
$$n_{air}\, n_{crystal} = n_{film}^2$$

Therefore refractive index of film (n_{film}) should have the value of

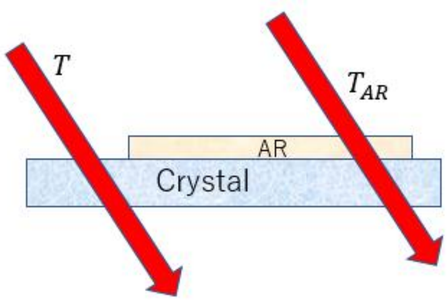
$$n_{film} = \sqrt{n_{air}\, n_{crystal}}$$

In our experiment, we chose the thin film known as cytop with the refractive index n= 1.3335 at λ = 1550 nm. The optical thickness of the film (d) required is computed as $\lambda/(4.n_{film})$ ~ 290 nm.

5. Experiment and results



$$T = \frac{I_{out}}{I_{in}}$$



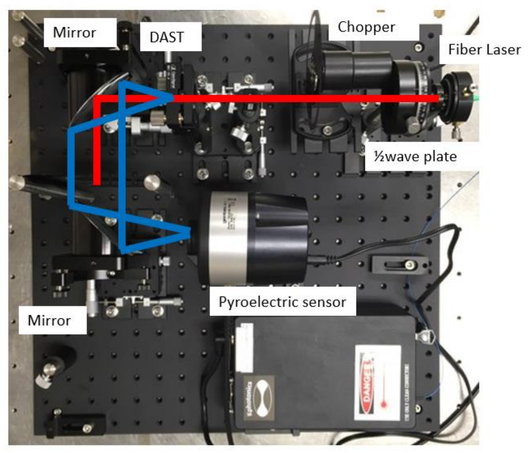
Transmittance of DAST crystal without AR coat

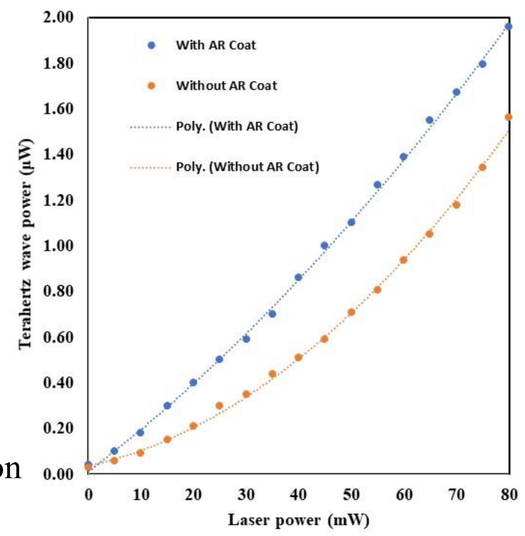
74.3 %

Transmittance of DAST crystal without AR coat

93.4 %

AR coat successfully reduced the Fresnel's reflection





5.Summary

In the study, we studied the terahertz wave emitted by DAST crystal with and without anti-reflection coating. We found that the power of terahertz wave generated by DAST crystal with AR coating is higher than the power of terahertz wave generated by DAST crystal without AR coating.

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