Investigation of Photocarrier Dynamics in Perovskite Solar Cells(PSCs) using LTEM(Laser THz Emission Microscopy)

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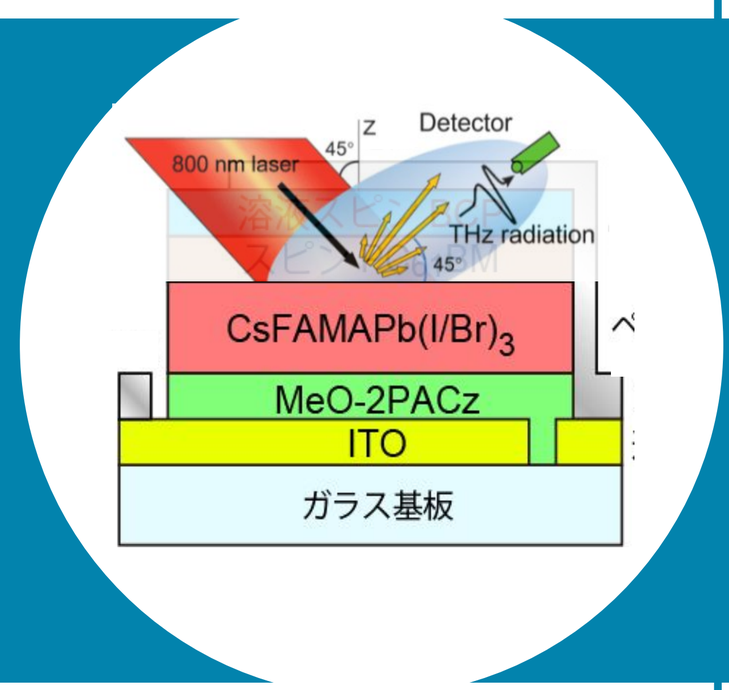
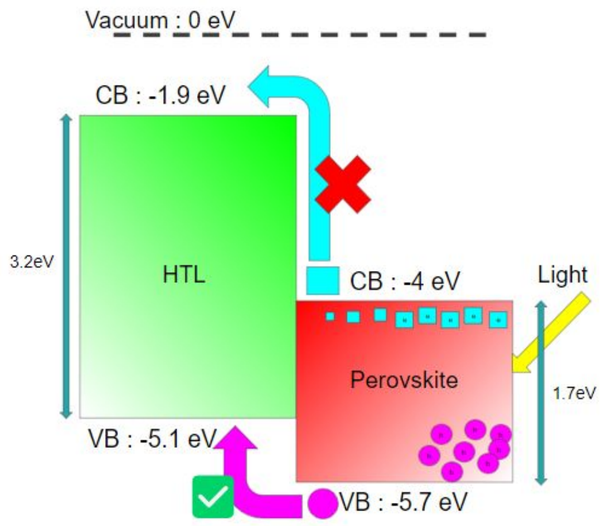
Background and Purpose

- **Why PSC ?** - High performance, which is even improved by applying layer of passivation
- Understanding the photocarrier dynamics(mobility, recombination, band structure, amount and direction of current) for further development is crucial
- Terahertz waves - Freq 0.1 THz to 10 Thz
- Unique properties - Non ionizing, Non Invasive, Penetration ability
- LTEM - Used for characterization of materials and understand their THz responses and carrier dynamics



Details of Perovskite Solar Cell

- Light weight, Low cost, thin and flexible solar cells
- Multi layer Structure : Hole transport layer(Green), Perovskite(Red), and Glass electrode.
- Passivation of PEACI solution



Band gap: Perovskite layer & HTL

Solar Cell samples

Method

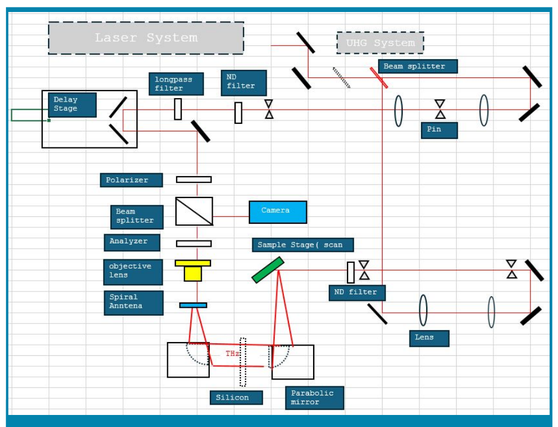
- Ultrashort femtosecond laser pulse on the PSC => produces terahertz waves.
- Sampling by lower power delayed probe pulse.
- Detection by using spiral PCA.
- LTEM for qualitative analysis
- Photo Dember effect vs Surge Current
- Checking the polarity, peaks amplitude and width.

Results & Conclusions

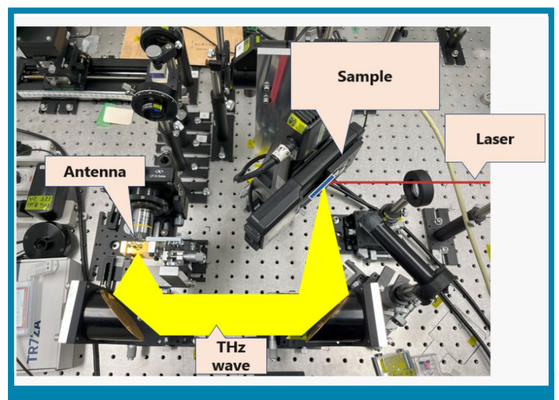
- THz waveform independent of the solar cell orientation.
- Passivation layer is changing the THz amplitude and peak positions both.
- The waveform is dependent on the laser wavelength, even if number of photons is kept same.
- Independent of orientation : Current is perpendicular to the surface, hence, Photo Dember effect is dominant.
- Carrier lifetime is less than the Laser repetition time(12.5ns)
- THz field peaks $\propto$ (Excess electron energy)$^{0.5}$

Theory

$$\mathbf{E}_{\mathrm{THz}} \propto \frac{\partial \mathbf{J}}{\partial t}$$

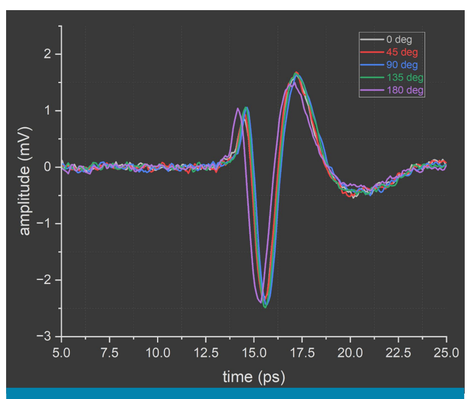


Optical Setup Schematic

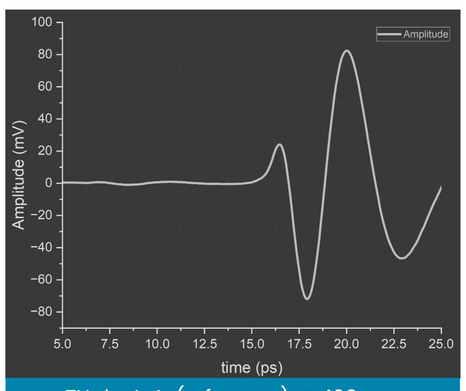


Laser hitting the sample

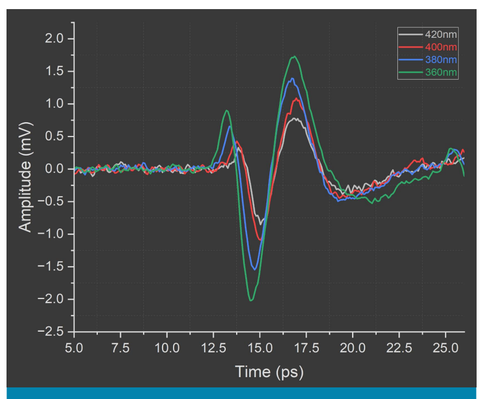
THz Waveforms from Solar Cells



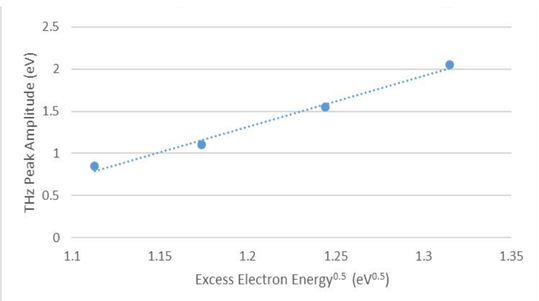
THz wave on Solar Cell Orientation



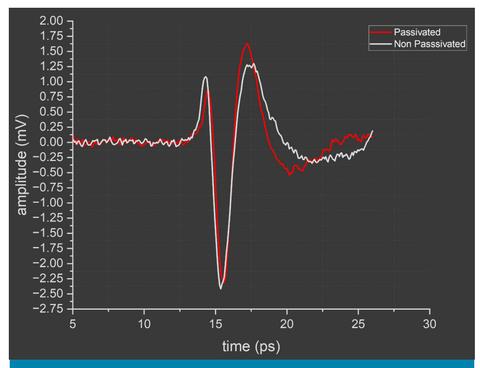
THz by InAs(reference) @ 400 nm, 36mW, 6mW



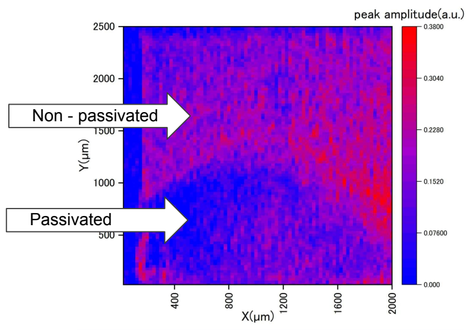
THz waveform dependence on wavelengths



THz Peak amplitude vs Excess Electron Energy$^{0.5}$



THz waveform dependence on passivation



LTEM image of Half PSC

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References
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