# Shape from Polarization of Thermal Emission and Reflection

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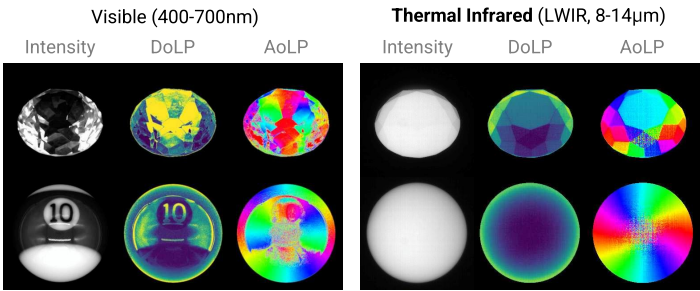Project Page

## Motivation

### Goal

- **Shape from Polarization** (SfP) in **thermal infrared spectrum**

### Observation

- Most materials are **opaque, uniform, emissive.**
- Clear relationship between polarization and shape.



Visible (400-700nm) — Intensity, DoLP, AoLP
Thermal Infrared (LWIR, 8-14μm) — Intensity, DoLP, AoLP

### Problems in prior work  (Partridge1995, Miyazaki2002, Kechiche2017)

- **Neglected reflection** and considered emission only.
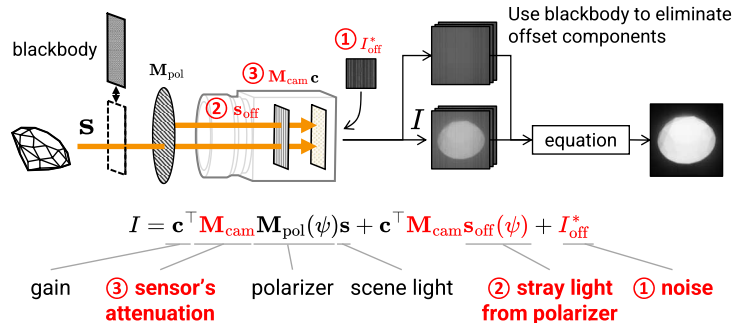- **Neglected error factors** of thermal polarimetry.

## Model & Method

### Polarization Model

- Emergent light is sum of **emission** and **reflection** components.
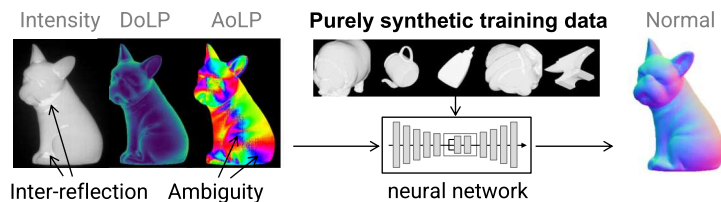- Polarization relates to the surface's orientation.



Surrounding radiance
Internal radiance
$\theta_R$  $\theta$  $\theta_T$
**Reflection + Emission = Combined Ray**
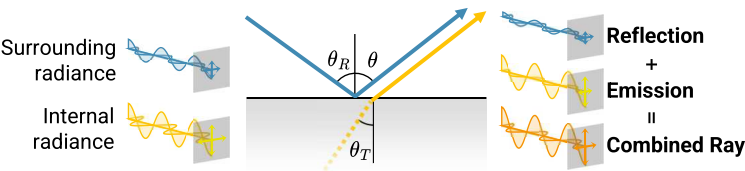
### Imaging System

- Compensate errors specific to thermal polarimetry.



blackbody
$\mathbf{M}_{pol}$
$\mathbf{S}$
② $\mathbf{s}_{off}$
③ $\mathbf{M}_{cam}\,\mathbf{c}$
① $I_{off}^*$
$I$
equation
Use blackbody to eliminate offset components

$$I = \mathbf{c}^\top \mathbf{M}_{cam}\mathbf{M}_{pol}(\psi)\mathbf{s} + \mathbf{c}^\top \mathbf{M}_{cam}\mathbf{s}_{off}(\psi) + I_{off}^*$$

gain | ③ sensor's attenuation | polarizer | scene light | ② stray light from polarizer | ① noise

### Recovering normal

- A neural network exhibits both robustness and physical fidelity.



Intensity  DoLP  AoLP    **Purely synthetic training data**    Normal
Inter-reflection  Ambiguity    neural network

## Experiments

- **ThermoPol** — the first thermal infrared SfP dataset



Object | Intensity | DoLP | AoLP | Estimated | Ground Truth

9.7°
7.6°



objects
$\tau_{obj} = 50°C$
$\tau_{env} = 23°C$

13.9°  13.2°  11.9°  9.4°
8.3°  9.7°  8.3°  7.1°
7.7°  9.9°  7.4°  9.2°
7.8°  23.4°

Average of MAE
10.3°

- Various materials



Glass   Acrylic   Phenolic
Wood    Stone

5.6°  6.8°  2.6°
3.3°  5.9°
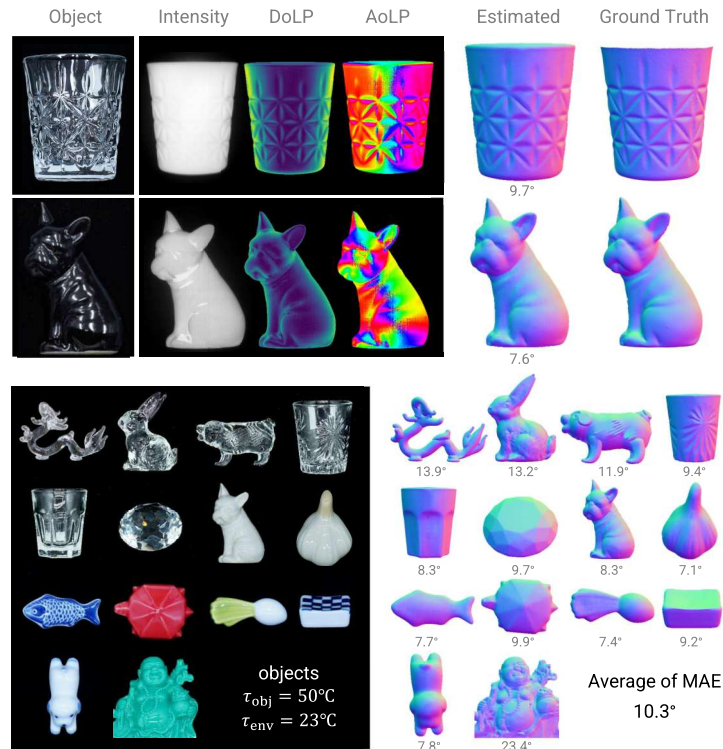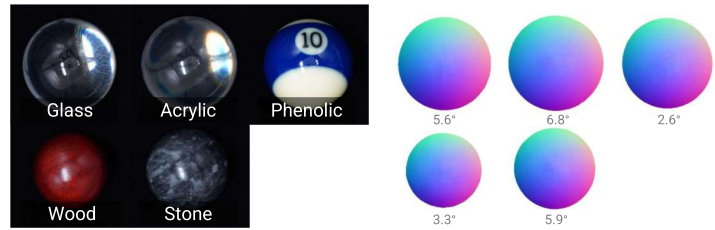
- Melting transparent ice



- Model-based method



7.2°  11.6°  10.5°

Mostly functional, but weak to low DoLP, inter-reflection, concave shape
Average of MAE: 13.6°
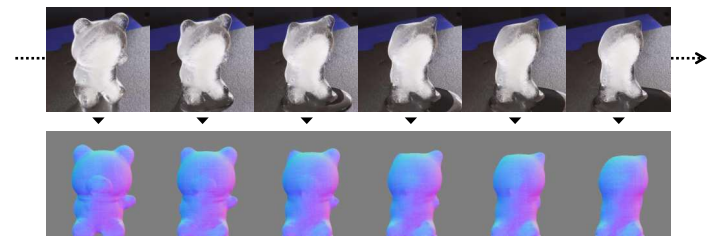
## Conclusion

### Takeaway

- Introduce SfP method in thermal infrared spectrum, accounting for both emission and reflection.
- Demonstrate high accuracy and broad applicability.

### Limitation

- Require thermal contrast
- Weak to certain materials (e.g., metal, rough surface)