Zone Plate Virtual Lenses for Memory-Constrained NLOS Imaging

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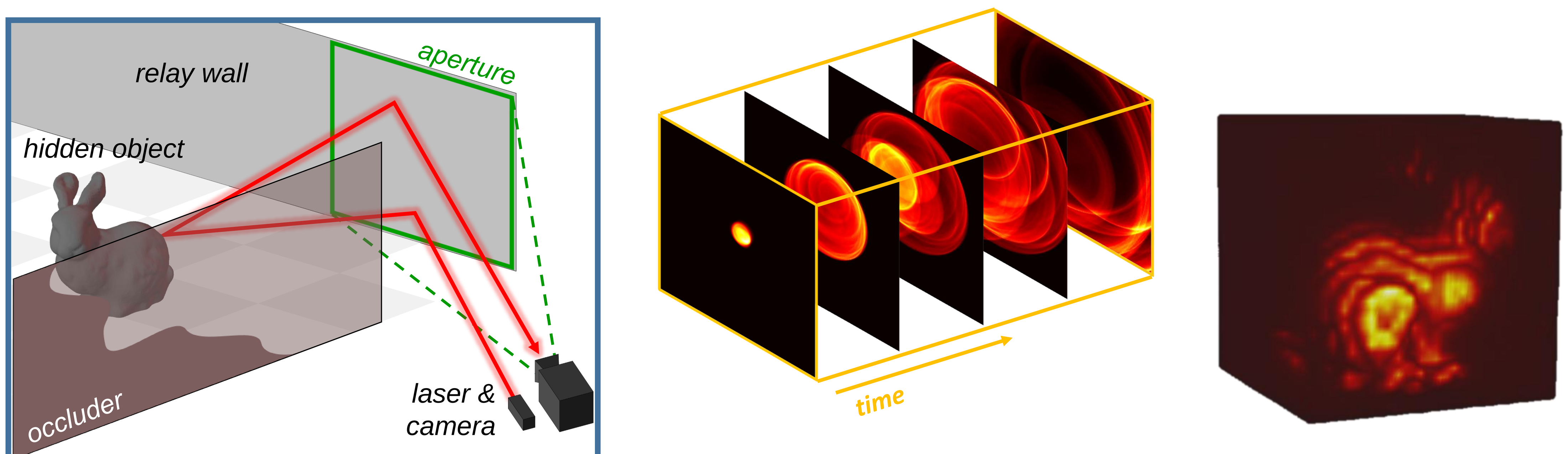
- **Non-line-of-sight (NLOS) imaging** exploits the transient imaging [1] to capture the indirect light of an occluded scene using a relay wall to look around a corner.
- The **Phasor Fields formulation** [2] reconstructs the hidden scene employing the Rayleigh-Sommerfeld diffraction (RSD) integral, whose most efficient implementations for parallel planes [3] are **heavy in memory.**

We **look around corners** reconstructing a hidden scene employing **virtual zone plates** that require up to **16 times less memory** if compared to previous approaches.

Time-resolved NLOS imaging

Transient imaging allows for capturing the light at **high temporal resolutions** [1] where the speed of light is not infinite. By illuminating and capturing a relay wall, it is possible to obtain **time-resolved images** from the **indirect light of the hidden scene**. There exists **non-line-of-sight (NLOS) imaging methods** to obtain 3D reconstructions from this signal.

Overview of the NLOS pipeline



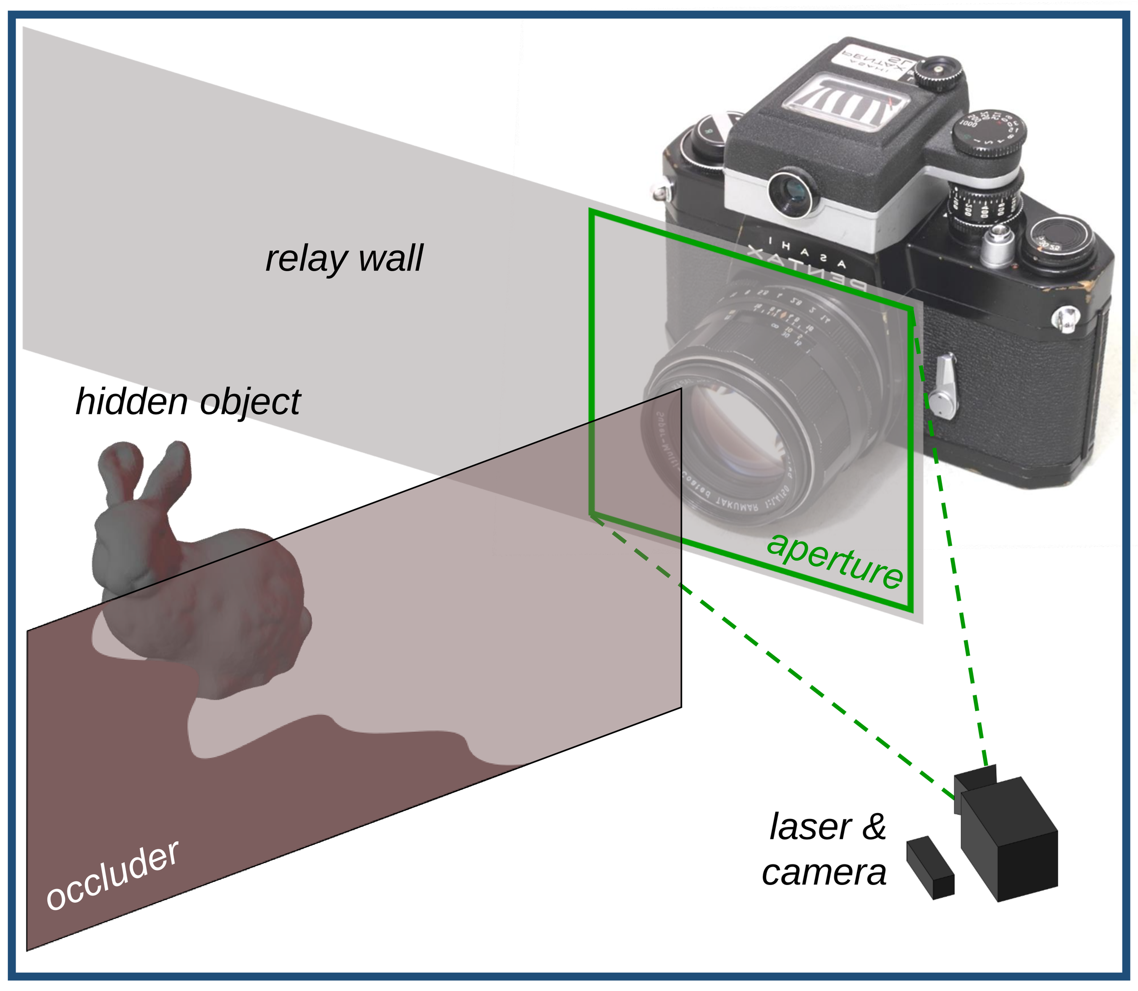
NLOS setup

Time-resolved images captured at the relay wall

Reconstruction

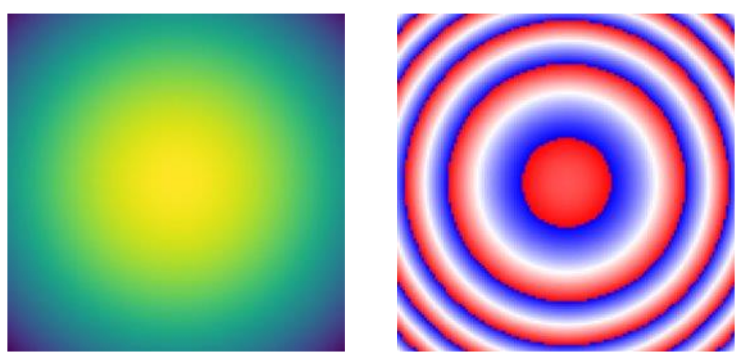
Phasor Fields and virtual focusing

Phasor Fields formulation transforms the time-resolved images into **virtual wavefronts**. Thus, focusing operators from the line-of-sight (LOS) field can be used to reconstruct (e.g. RSD). **We propose a propagation based on the zone-plates (ZP)** to bring an approximate focus of a hidden scene.



Phasor Fields formulation

RSD-based kernel



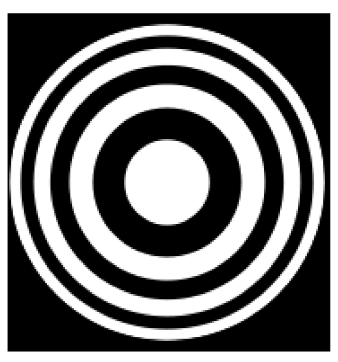
amplitude *phase*

Example of RSD-based kernel to obtain the exact diffraction

$$\mathcal{R}(\boldsymbol{x}_k, f, \omega) = \frac{e^{-i2\pi\omega\sqrt{|\boldsymbol{x}_k|^2+f^2}/c}}{\sqrt{|\boldsymbol{x}_k|^2+f^2}}$$

$\mathcal{R}(\boldsymbol{x}_k, f, \omega) \in \mathbb{C}$ **16 bytes**

Our ZP-based kernel



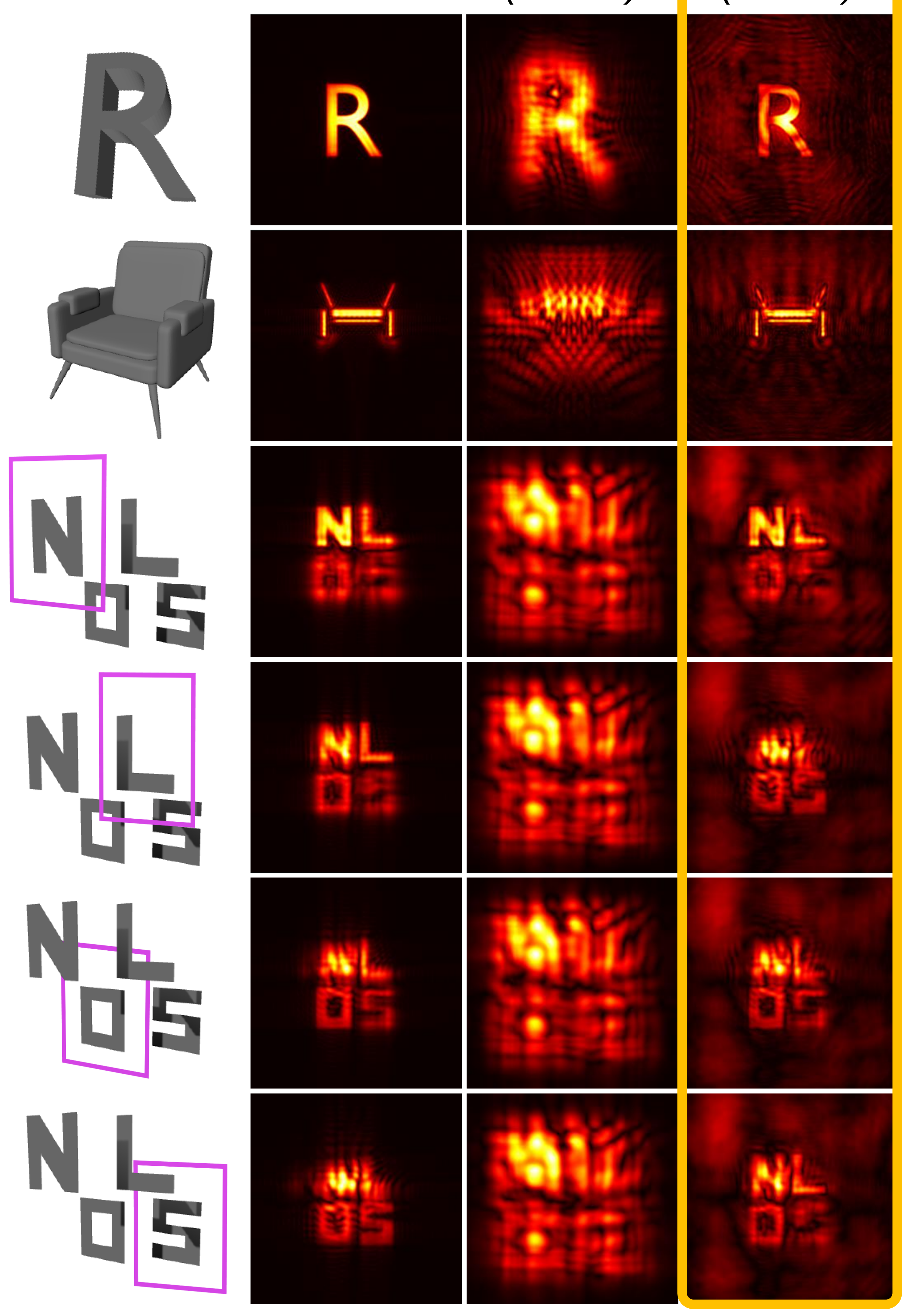
A zone plate focus a wavefront using diffraction, using concentric rings of opaque and translucent.

$$\mathcal{R}(\boldsymbol{x}_k, f, \omega) = 2\left(\frac{2}{\lambda}\left(\sqrt{|\boldsymbol{x}_k|^2+f^2}-f\right) \bmod 2\right)-1$$

$\mathcal{R}(\boldsymbol{x}_k, f, \omega) \in \{-1,1\}$ **1 byte**

Results

Scene | ***RSD-based kernel*** *(1 GB)* | ***trimmed RSD-based kernel*** *(64 MB)* | ***Our ZP-based kernel*** *(64 MB)*



Future work: to apply operators based on **other lenses** in the Phasor Fields formulation (e.g. for non-parallel surfaces)

References

[1] - Andreas Velten, Di Wu, Adrian Jarabo, Belen Masia, Christopher Barsi, Chinmaya Joshi, Everett Lawson, Moungi Bawendi, Diego Gutierrez, and Ramesh Raskar, "Femto-photography: capturing and visualizing the propagation of light," *ACM Transactions on Graphics (ToG),* vol. 32, no. 4, pp. 1–8, 2013.

[2] - Xiaochun Liu, Ibón Guillén, Marco La Manna, Ji HyunNam, Syed Azer Reza, Toan Huu Le, Adrian Jarabo, Diego Gutierrez, and Andreas Velten, "Non-line-of-sight imaging using phasor-field virtual wave optics," *Nature*, vol. 572, no. 7771, pp. 620–623, 2019.

[3] - Xiaochun Liu, Sebastian Bauer, and Andreas Velten, "Phasor field diffraction based reconstruction for fast non-line-of-sight imaging systems," *Nature communications*, vol. 11, no. 1, pp. 1–13, 2020

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