# Shoot to kill

Spatial light modulators to activate small neural populations simultaneously

Gergo Bohner 4<sup>th</sup> April 2014 Gatsby tea talk

### Order of Business

- 1. The Experiment
- 2. The Optics
- 3. The Problems

#### 4. The Solution?

## The Experiment

Activate a subset of cortical neurons and record from many around to investigate neural circuits.

- Mice infected via adeno-associated virus with opsin (C1V1<sub>T</sub>)
- Find affected neurons (e.g. virus co-expressing EYFP), choose targets for stimulation
- Simultaneously activate the target neurons (induce spikes)
- Record activity from neurons, see how the activation of the stimulated neurons affect the circuit.

## The Experiment



## The Optics

Use spatial light modulators to split laser beam and create maxima at pre-specified locations

 Phase-only Spatial light modulators (PO-SLMs) consist of electronically addressable pixels that can create retardation of the incoming wavefront thus creating "arbitrary" phase-pattern in the SLM plane, which thereafter propagates to the far field and interferes with itself, creating the desired patterns.



## The Optics



Figure 1. Side view of an LCOS-SLM device. A wavefront entering the device is phase modulated by varying voltage on the individual pixels, which in turn rotates the LC molecules above the pixel.



#### SLM pattern produced

## The Optics

 Gerchberg-Saxton (1972) algorithm to iteratively optimize SLM pattern



### The Problems

- Phase and pixel quantization
- wavefront correction
- inter-pixel crosstalk



#### The Problems

Tradeoff between field of view and power?





BNS 30 spots on fluorescent slide



#### Machine Learning: The Solution?

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- Add constraints and project to find best solution?
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### Machine Learning: The Solution?

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- Add constraints and project to find best solution?
  Impossible, we cannot define all constraints.
- Extremely cheap to collect data, ~30 ms to set new SLM pattern, BUT very high dimensional (maps from 512\*512\*256 to 512\*512\*256)
- Learn the much lower dimensional basis of SLM patterns that create spot-patterns in the far field
- In this representation, learn the association between SLM and far field patterns
- Predict good SLM patterns for desired far field ones

## Today's Recipe

- Take a bit of a neuroscience dream experiment, that is coming true
- Add cool laser physics stuff
- Spice it up with machine learning to solve what physics can not

Let everyone have tea and biscuits

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#### References

- Spatial Light Modulator Microscopy (Nikolenko et al, 2013, CSH, Yuste lab)
- Targeting neurons and photons for optogenetics (Packer et al, 2013, Häusser lab)
- Two-photon optogenetics of dendritic spines and neural circuits (Packer et al, 2010, Yuste lab)
- Synthesis of Three-Dimensional Light Fields and Applications (Piestun & Shamir, 2002)