Imaging and Analysis Tools for Optogenetic Cardiac Electrophysiology

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Cardiac arrhythmias are characterized by excitation waves with complex spatio-temporal dynamics → Scientific challenge

Optogenetics provides the tools to overcome this challenge.

Ventricular arrhythmias ~15% of all deaths

Treatments: drug therapy, electrical shock
Optogenetics

Optics + genetics bioengineering

Control cellular activity via light-sensitive proteins

Channelrhodopsin-2 blue-light sensitive ion channel
Optogenetics

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bioengineering

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Control of membrane voltage potential of excitable cells
neurons, cardiomyocytes
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Action potential $\rightarrow$ Heart electrical
synchronization
Cardiac Optogenetics

- Temporal control
  [Bruegmann, 2010], [Abilez, 2011]

- Photocurrent
  [Abilez, 2011]

- Action potential response
  [Bruegmann, 2010]

- Optical pacing properties
  [Jia, 2011]

- Spiral wave arrhythmia termination
  [Bingen, 2014]

- Control of electrical waves
  [Burton, 2015]

- Cell type-specific control
  [Zaglia, 2015]

- Defibrillation patterns
  [Crocini, 2016]
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Goal

Development of an optogenetic stimulation, imaging and data processing system as a tool to investigate electrical wave dynamics with aims on ventricular arrhythmia termination.
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- High temporal and spatial resolution **pattern generation** for stimulation
- **Image** acquisition and analysis (voltage)
- **Closed-loop control** of the system
Optogenetic System

- Light-pattern Generation (DMD)
- Image Acquisition
- Software
- Feedback Loop
Digital Micro-mirror Device testing

• Software

• 11.45 mm Diagonal Micromirror Array
  – 912x1140 mirrors

• Pattern display mode
  – 1-Bit Binary pattern rates to 4 KHz
  – 8-Bit Grey-scale pattern rates 120 Hz

• Flash memory → 64 24-bit compressed images.
  → 24, 1-bit pattern
Light-response characterization

- Ex vivo, ChRh2- transgenic mouse hearts.
Light-response characterization

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- Optic fiber + 470 nm LED.
- MAP electrode.
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- Optical stimulation varying:
  - Optical fiber surface area
    0.126 mm$^2$, 0.785 mm$^2$
  - Pulse length
    1-10 ms, 15 ms
  - Light intensity
Light-response characterization

- 100% response
References


