# Beam Stabilization and Instrumentation Systems based on Internet of Things Technology

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## Statement of the Problem

- MaxIV is a 3 GeV synchrotron light source operating at an RF frequency of 100 MHz with enough installed power for over 250 mA of beam current.
- MaxIV is designed to operate in the long bunch mode (bunch lengths > 500 ps rms) using passive third harmonic Landau cavities.
- As of **April 2018**, it was not possible to operate in long bunch mode because of longitudinal instabilities.
  - MaxIV does possess a longitudinal bunch-by-bunch feedback system but the system was not effective in the long bunch mode.
  - It was surmised that the longitudinal instability was a dipole mode 0 coupled bunch mode instability but there were no diagnostics to definitively prove this assertion.

## Constraints

- MaxIV is a small lab (< 200 people) with limited human and financial resources.
- Delay in beamline construction has absorbed the most of the control system resources. There are limited software and IT resources available.
- Limited technical resources. Engineers design and build their own electronics boards.
- Limited financial resources.

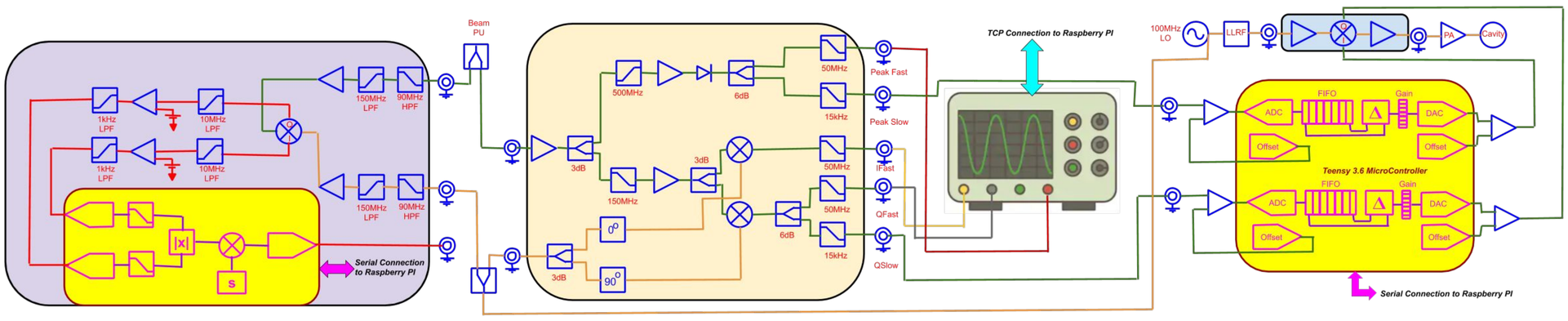
## Steps to Solution

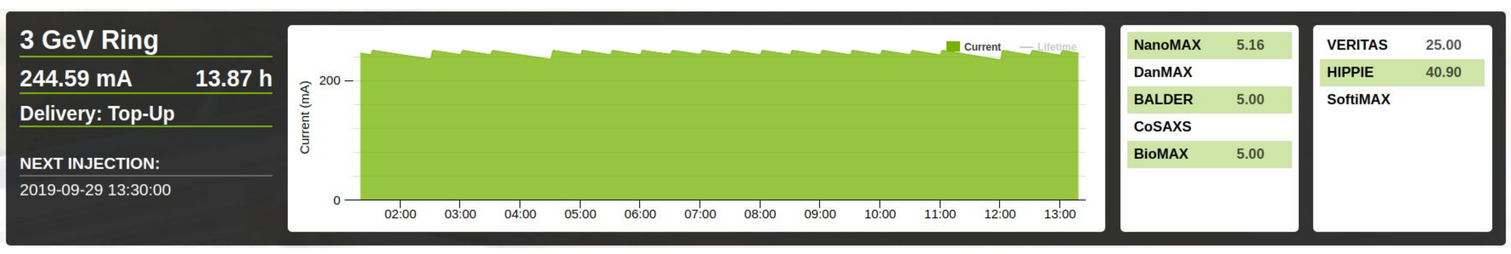
- Build a coupled bunch mode analyzer diagnostic to determine which coupled bunch mode instabilities are present and the growth rate of these modes.
- Build narrow band but high gain coupled bunch feedback systems to damp offending modes.
- Use Blinky-Lite, an open source IOT control platform for controls and data acquisition.
- In **June 2018**, coupled bunch mode analyzer commissioned and Mode 0 instability identified.
- In **September 2018**, Mode 0 damper commissioned
- In **October 2018**, long bunch operation at MaxIV was operational

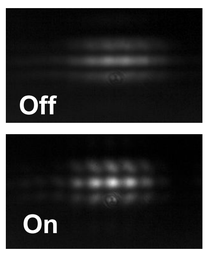
***Radio Frequency Current Transformer***

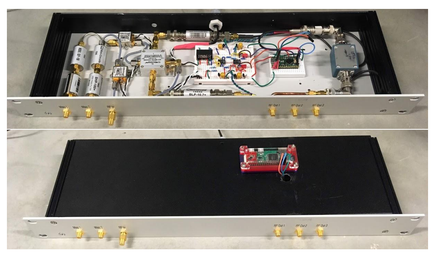
***Coupled Bunch Mode Analyzer***

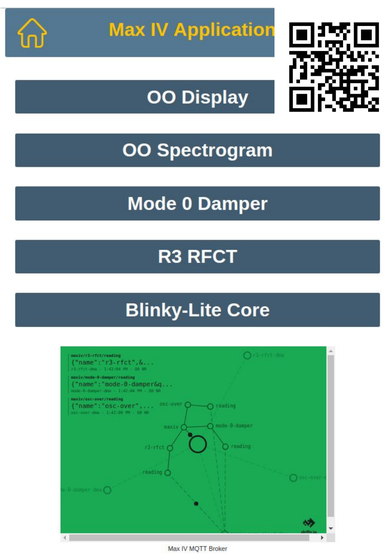
***Mode 0 Damper***

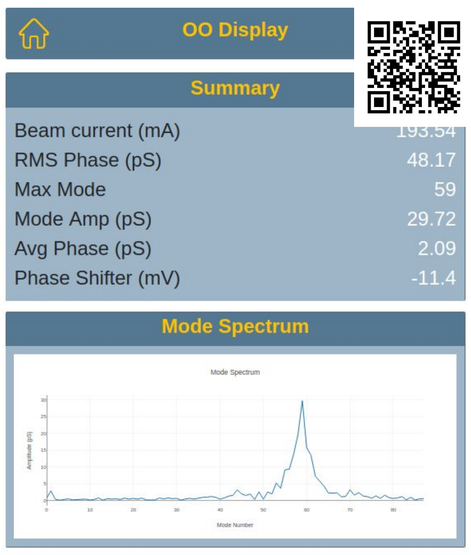


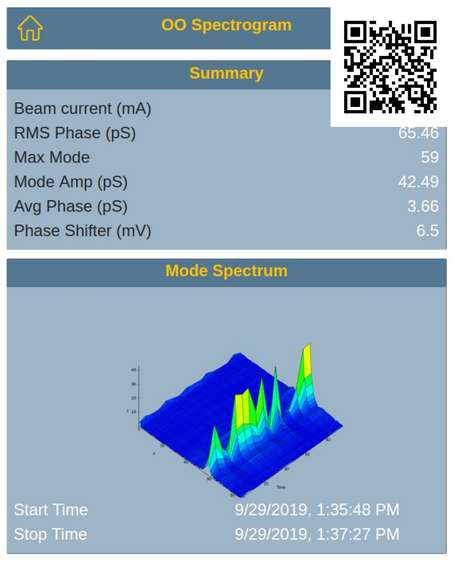



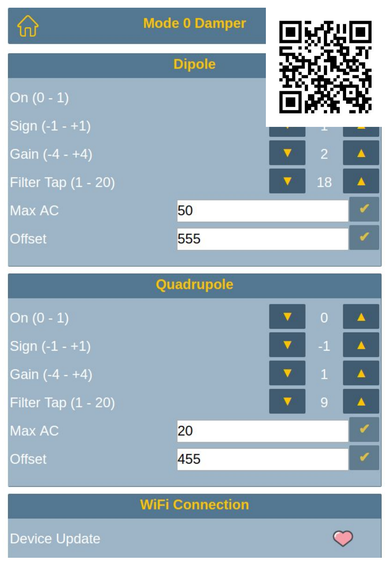







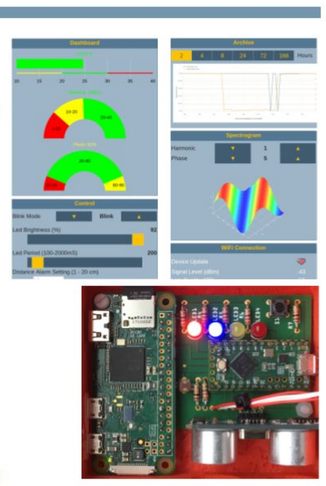
## Blinky-Lite Controls for humans

*An open source IoT Control Platform*

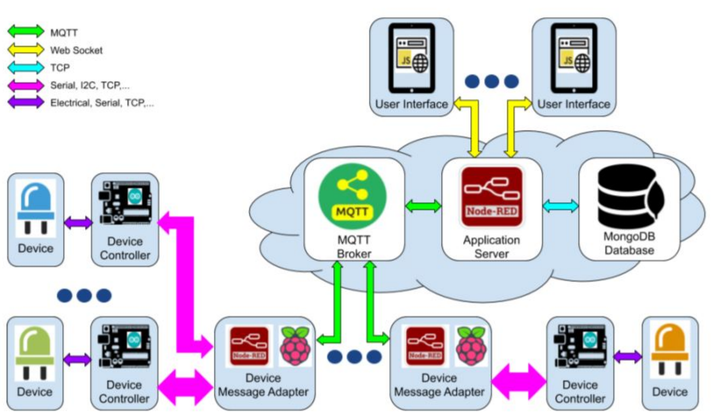
- **Extremely reliable and robust control**
  - Blinky-Lite is based on high performance but inexpensive IoT computing placed *close* to the devices to control.
- **Web Accessibility**
  - Blinky-Lite applications are web-based giving control from anywhere in the world.
- **Flexibility**
  - Blinky-Lite is 100% open source for easy customization
- **Easy to implement**
  - Blinky-Lite is designed for non-experts who have beginner knowledge in Javascript.

https://www.blinky-lite.io/

https://github.com/Blinky-Lite

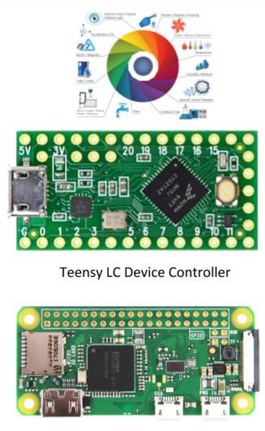


## Blinky -Lite Architecture




## Blinky Lite Components

- Device
  - Plethora of IoT sensors and actuators
- Device Controller
  - Interfaces directly with device sensor and/or actuator through ADC, PWM, Digital I/O or DAC pins
  - Communicates (serially, I2C,...) to the Device Message Adapter (DMA)
  - Usually programmed using the Arduino IDE
- Device Message Adapter (DMA)
  - Communicates with a number of Device Controllers
  - Concentrates and scales device data
  - Translates data to and from the MQTT broker
  - Programmed in Node.js with the Node-RED programming environment



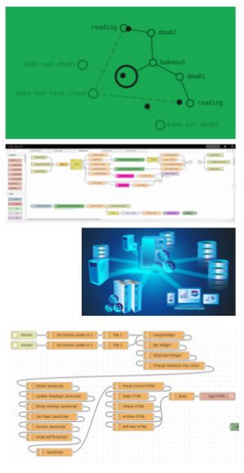
Teensy LC Device Controller



Raspberry Pi Zero DMA

## Blinky Lite Components

- MQTT Broker
  - *Can be cloud based*
  - Receives and transmits messages to DMA's
  - Receives and transmits messages from to the WAS
- Web Application Server (WAS)
  - *Can be cloud based*
  - Collects and transmits data to DMAs and user applications
  - Archives data to MongoDB database
  - Serves user applications
  - Handles authentication
- MongoDB database
  - *Can be cloud based*
  - Archives data
  - Records are JSON documents
    - matches well with Node.js and Node-RED
    - Non-relational - easy to extend
- User Application
  - Web based for easy deployment
    - mobile first but not mobile only
  - Written in Javascript
  - Communicates to the Web Application server via web-sockets



## Blinky Lite Features

- Cloud capable - Cloud deployments give enhanced:
  - Accessibility and deployment capability,
  - Along with enhanced reliability and security (https:// and wss://),
- Layered authentication
  - JSON Web Tokens for client-server transactions
  - Authenticated MQTT broker for server-device transactions
- JSON Device configuration
  - Flexible data types (scalar, vector, text, images, blobs,...)
  - Human readable and configurable
- MQTT and Websocket communication
  - Publish-subscribe instead of polling protocols
- SMS Alarm notification
- Graphical Node-Red code environment
  - Re-usable code
  - Self documentation

## Blinky Lite Features

Eight web-based core applications