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IPRO 309

Building an Integrated Turn-Key X-Ray Fluorescence Analysis System Using Bent Laue Optics

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Background

- X-Ray Absorption Fine-Structure (XAFS)
  - Hit sample with energetically tuned X-ray beam
  - Sample emits unique spectrum of X-ray photons
  - Collect and measure desirable photons
  - Discard background (noise) photons

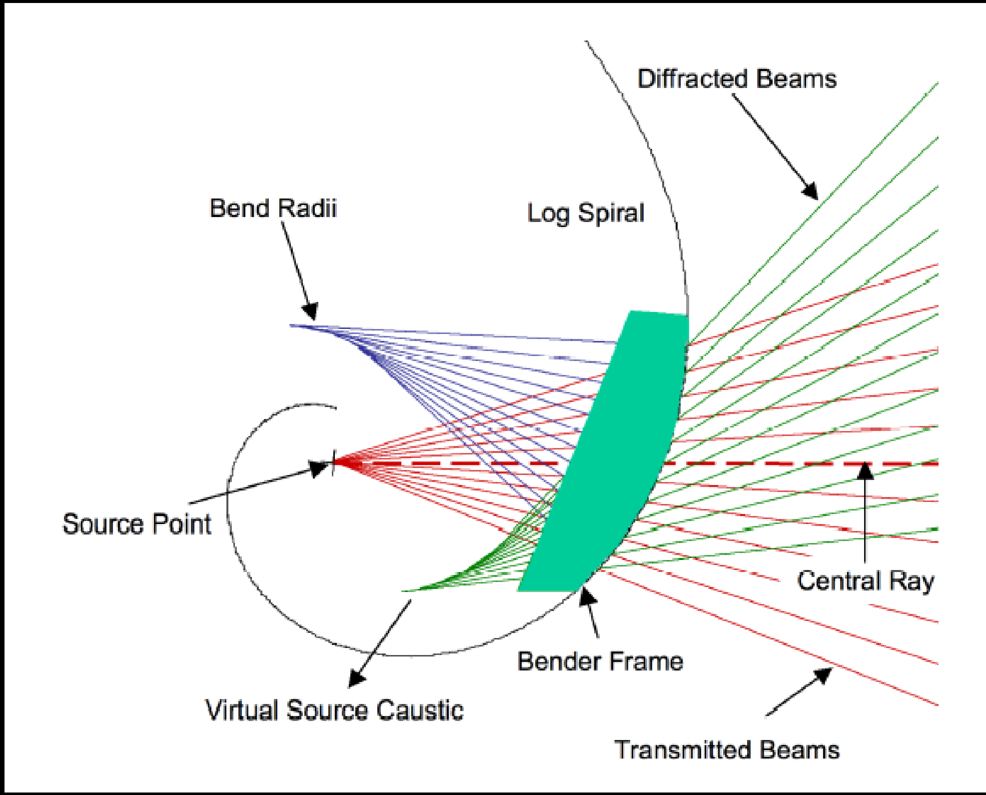

Diagram of BCLA Diffraction Paths

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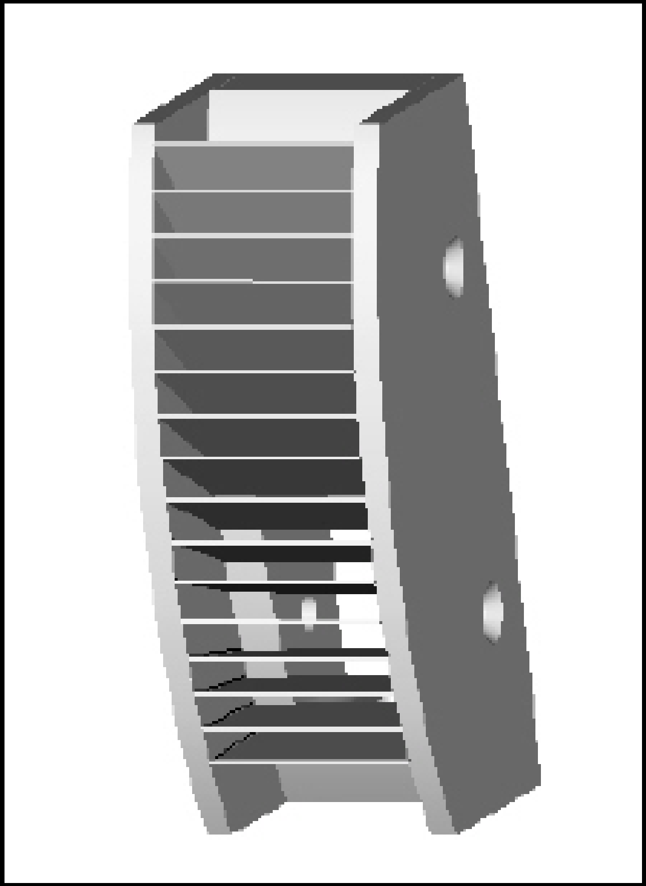
Bent Crystal Laue Analyzer

- Problem: Conventional Detectors are Inadequate
  - Solid state detectors saturate easily
  - Poor energy resolution
- Solution: Bent Crystal Laue Analyzer (BCLA)
  - Diffractive filtering device
  - Good energy resolution and collection efficiency
  - Inexpensive compared to complex silicon devices



Pro/E Model of BCLA Bender Frame

Objective

- Integrate BCLA into marketable system
  - Investigate promising technologies
    - Research and evaluate current products
    - Procure/construct viable solutions
    - Test designs
  - Balance engineering aspects of project
    - Performance
    - Ease of use
    - Cost of manufacture
  - Design prototype

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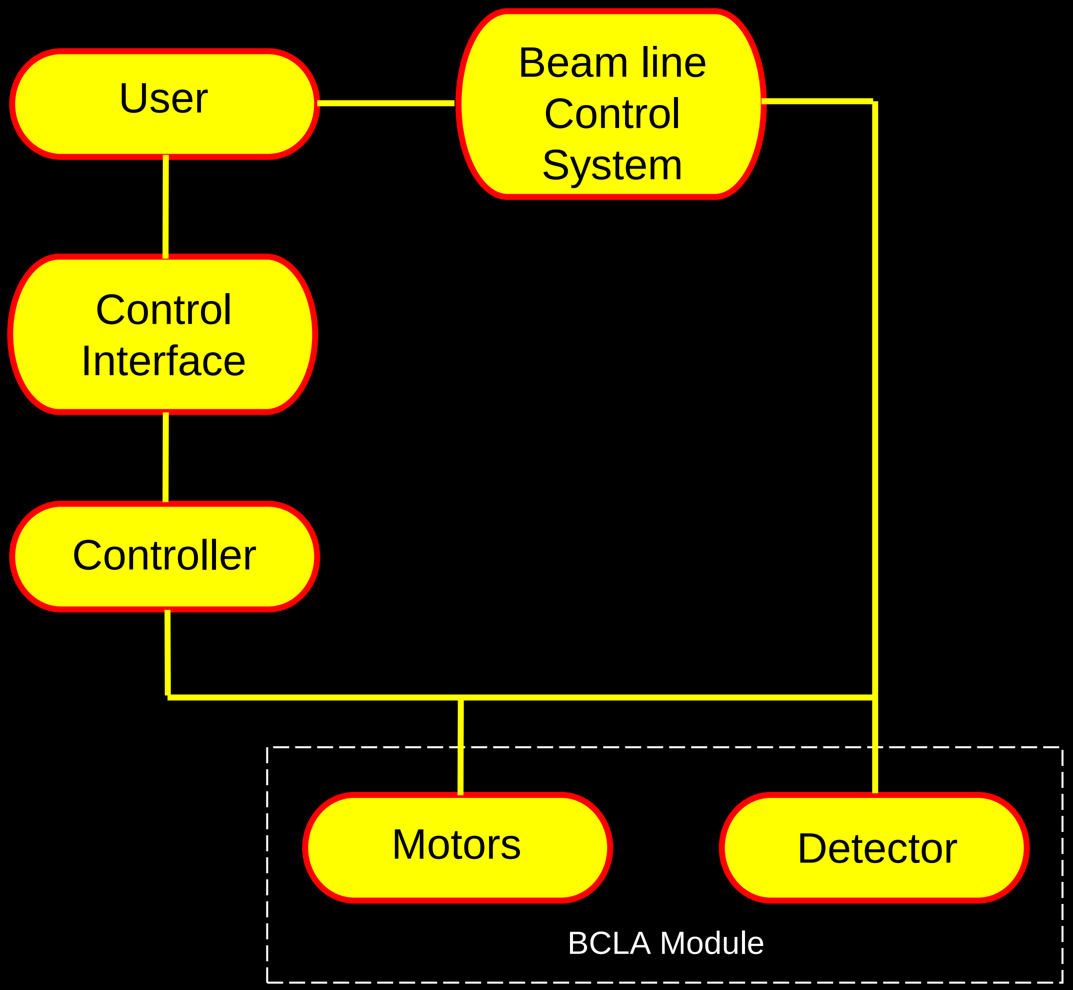
Conceptual Design



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Research Groups

- Motion control
  - Research practical positioning technologies
  - Obtain suitable product(s)/system(s)
- Detectors
  - Investigate X-ray detector technologies
  - Design and test detector/amplifier systems
- Data acquisition and control
  - Interface motion control and detector systems
  - Prepare alignment software

Motion Control

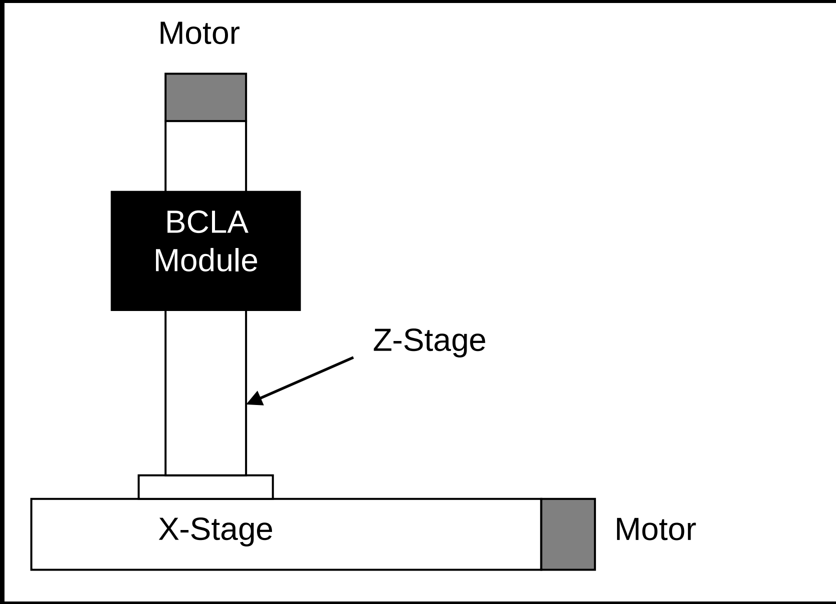
- Objectives
  - Integrate smoothly with other components
  - Economic viability
  - Specs
    - Size
    - Range of Motion
    - Spatial Precision
      - X-Axis Resolution/Repeatability
      - Z-Axis Resolution/Repeatability

Motion Control

- Motors
  - Piezo Electric
    - (nm) resolution
    - Expensive
  - Servo
    - Cheap
    - Requires (expensive) feedback hardware
  - Stepper
    - Economical
    - Load independent
    - Feedback optional

Motion Control

- Stages
  - Linear Stages
    - Economical
    - Good precision
  - Z-Wedges
    - Compact
    - Precise
    - Expensive



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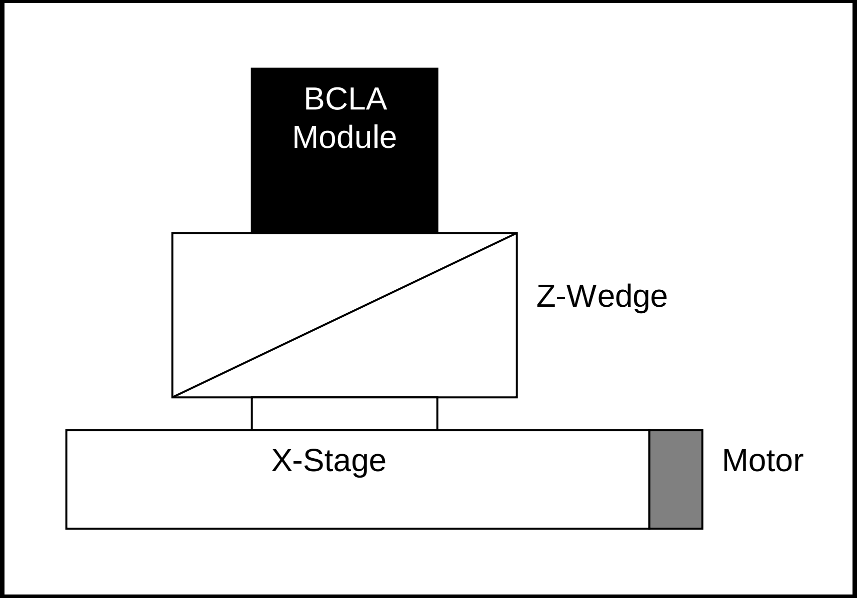
Motion Control

- Stage Assemblies
  - Orthogonal Linear Stages
  - Linear Stages with Z-Wedge
  - Non-Orthogonal Linear Stages



Detectors

- Specifications
  - Detectors
    - Response on the order of 1 MHz
    - Detect X-Ray energies ~6-30 keV
  - Amplifier(s)
    - Amplify current signal on the order of nA
    - Provide suitable voltage signal for data acquisition
- Considerations
  - Compact size for on-stage instrumentation
  - Light weight

Detectors

- Solid-state detectors
  - PIN diodes
  - Avalanche photodiodes
  - Passively-implanted planar silicon (PIPS) detectors
  - Multi-element solid-state arrays
- Ionization chambers
- Scintillator/photomultiplier tubes
- Proportional Counters

Detectors

- Amplifier
  - Integrating operational amplifier
    - Low input bias current
    - No large feedback resistor
    - Noisier at lower count rates
    - Output-voltage hold capability
- Data conversion
  - Analog-to-digital conversion (ADC)
  - Voltage-to-frequency conversion (VFC)

Detectors

- Conclusions
  - Inexpensive solid-state detector (PIN diode, PIPS)
  - Use simple op-amp integrating circuit amplifier
- Recommendations
  - Test detectors in multiple configurations
    - Parallel-1 amplifier
    - Parallel-individual amplifiers
  - Test integration w/ microcontroller (if used)
  - Test multiple detector array geometries

Data Acquisition and Control

- Interfacing
  - Motion control systems
  - X-ray detectors
- Integration
  - Develop a system that performs automatic alignments, using the motion control system and x-ray detector
  - Allow existing instrumentation to easily collect data from the x-ray detector
- Considerations
  - DAC cannot contribute much to manufacturing cost
  - Final product must support multiple configurations

Data Acquisition and Control

Interfacing

- Research
  - Communications standards
  - Protocols and command languages
  - Signals from X-ray detectors
- Current Applications
  - MDrive 17 stepper motor
  - PDA 750 amplifier
  - PC-based prototype

PDA 750 Transimpedance Amplifier

MDrive 17 Microstepping Motor

Data Acquisition and Control

Integration

- Automatic Alignment
  - System controller
  - Alignment algorithm
  - User interface
- Existing Instrumentation
  - Typical equipment chain
  - Signaling standards
  - Voltage-Frequency conversion

Data Acquisition and Control

- Conclusions
  - Use Linux-based software for beamline integration
  - Use PC data acquisition card for A/D conversion
  - Positioning software needs more work
- Recommendations
  - Further develop positioning software
  - Work with groups to prevent project complications

Project Obstacles

- Lab Space
- Products specs (tech reps)
- Improper lab equipment
- Computer failure
- Physical system integration

Expenditures To Date

Two PCs	$1,600
books	$270
Two linear stages	$1,200
Two IMS MDI17 motors	$400
Two terahertz technologies RS232 amplifiers	$1,800
1 PIN diode/stand	$100
30 PIPS detectors (used on EBay)	$160
A/D converter board	$300
ZWorld Coyote single board controller	$200
Prototyping workstation and DVM	$300
Dual bench power supply	$250
Electronics supplies	$300
Cleaning and painting costs	$850
Two Microfocus X-Ray generators (Cu&W)	$43,000
Total	$50,730

Learning Objectives

- Completed objectives
  - Project management
  - Effective communication
  - Information organization
  - Equipment procurement and testing
- For next semester
  - Information assessment
  - Completion of system integration
  - Test and modify prototype design
  - Continued research and development

Questions?