A Coded Aperture Magnetic Sector Mass Spectrometer

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Motivation: Miniaturizing a Mass Spectrometer

• Goals
  − Reduce size, cost, and power consumption in mass spectrometry by two orders of magnitude

• Applications
  − Space: Mars and lunar rover
  − Medical: Analyze blood chemistry
  − Military/Security: Chemical/biological hazard alert
  − Environmental: Sense pollutants

CAMMS System Components

- MEMS electron ionization source
  - CNT field emission electron source
- Microfabricated ion detector array
- Permanent magnet mass filter
- Coded Aperture at Ion Source Exit for improved SNR
- For more information see poster by Erich Radauscher (presented by Charles Parker)

Coded Aperture Motivation and Presentation Outline

• Miniaturized systems suffer from reduced signal intensity

• Aperture Coding has been used in Optical Spectroscopy to dramatically boost Signal To Noise Ratios
  − [David J. Brady, Optical Imaging and Spectroscopy Wiley-OSA, 2009]

• Presentation Outline
  − Aperture Coding in Optical Spectroscopy
  − Aperture Coding in Mass Spectroscopy and Ion Optics
  − Proof of Concept Test Bed Design and Component Focus
  − Experimental Results showing 15x intensity improvement
  − Summary, Conclusions, and Future Work
Aperture Coding in Light Optics

Detection Plane
Dispersion Element
Small Slit
Large Slit
Coded Aperture


Coding Magnetic Sector Instruments

Faraday Cup
Detector Array
Volume of Ion Trajectories

Mass Spectral Library Compressibility

Spectral Library

Number Index

m/z

Singular Values Covariance Matrix

Eigenvalues

Proof Of Concept Test Chamber

1. Custom built El source from Kimball Physics stainless steel ev parts
2. 0.45 T bar magnet and yoke from Dexter Magnetics
3. 40 mm 32 micron pitch multichannel plate with phosphor screen detector from Beam Imaging systems

predicted Coded Aperture Merit

Neir Type El Ion Source

Limited Angular Dispersion <0.5° as measured experimentally

Beam Energy = 999.8 ± 0.3 eV <0.3% Dispersion
Hadamard Coded Apertures

Hadamard patterns were chosen due to their ease in incorporation into the forward model. The apertures were fabricated via deep reactive ion etching (DRIE) of 250 micron thick silicon wafers with feature sizes down to 25 microns.

Aperture Fabrication

Thru holes and slits as small as 10um (minimum feature size) were fabricated in this way.
• The inverse of the Forward Matrix allows transformation of the raw data into the mass spectrum.
• The Forward Matrix is derived from the physics of the system and geometry of the coded aperture
• For additional information see poster by Evan Chen (presented by Zach Russell)
**Future Work**

**Micro Component Integration**

**Mattauch Herzog Geometry**

**Cycloid Geometry**

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**Abstract (for reference only)**

- The ultimate goal of this project is to develop a coded aperture microfabricated mass spectrometer (CAMMS) [1]. This instrument concept is based on integrating aperture coding [2], used primarily in optical spectroscopy, with a carbon nanotube-based field emission source, charged particle optics on a microfabricated MEMS (MicroElectroMechanical Systems) platform and a permanent magnet magnetic sector. MEMS technology has been shown to be an excellent platform for the development of miniaturized charged particle devices [3]. However, decreased throughput and small sample sizes in microfabricated instruments are expected to lead to diminished performance. To minimize this degradation in performance we are investigating the principles of multi-aperture coding [1]. Use of coded apertures can eliminate the historical trade-offs between resolution and signal intensity in a mass spectrometer. Our current focus is proof of concept work on the application of coded apertures to ion optics in a testbed with a traditional thermal electron ionization ion source. The charged particle simulation program SIMION is utilized to inform system design as well as to establish appropriate working conditions for electrostatic lens systems. This presentation will include: (i) the microfabricated system concept, (ii) the coded aperture-testbed design and optimization, and (iii) results from Hadamard coded apertures that have been shown to provide a 15x increase in throughput as compared to single slits without sacrificing mass resolution.