Digitally Addressable X-ray Sources for Imaging

CIRMS Meeting
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Stellarray, Inc.
Austin, TX

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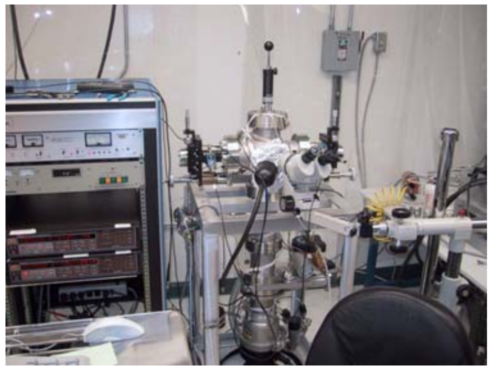
Company Overview

- **Background**
  - formed December 2007
  - subsidiary of Stellar Micro Devices, R & D firm, flat panel displays
  - specialize in vacuum nanoelectronics
- **People**
  - 16 technical staff and growing
  - expertise in cathodes, vacuum & radiation systems, high voltage
- **Business**
  - manufacture and sell radiation panels and products using them
  - funded mainly by SBIR, NIST ATP, NIH
  - NIH SPAN - irradiator commercialization & platelet shelf life extension
  - SCBI is first branded product
- **Facilities**
  - 10,800 sq ft of lab and production space
  - full range of photolithography, test, machining, vacuum equipment
  - panels up to 20”
  - accommodate first few years of panel and SCBI production
  - shielded radiation test room



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Background to DAXS

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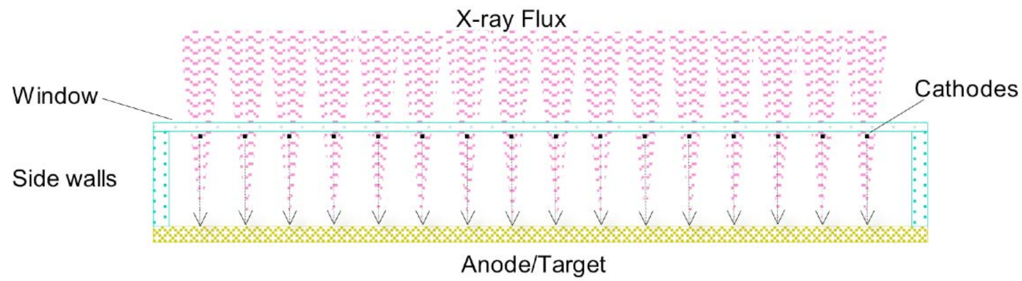
- **X-ray/UV-C Source for Biohazard Decontamination**
  - AFRL SBIR, 2004-2007
  - combined source - target anthrax spores
  - background in field emission displays - cold cathode arrays
    - arrays over X-ray target - *reflective* X-ray source
    - arrays over phosphor - cathodoluminescent UV-C
- **Flat Panel X-ray Source**
  - NIST ATP project, 2007 - 2010
  - manufacturing systems and processes
    - materials systems for modules
    - process tools for cathode thin films
    - cathode array fabrication processes
    - driver circuits, on-board HV amplifiers



- **General Characteristics**
  - same physics as a tube, change the architecture
  - *cathode arrays on the exit window*
  - X-rays up from target, out window
  - less heel effect, > 3X power efficiency
  - easy to cool anode from back
  - can make in various sizes

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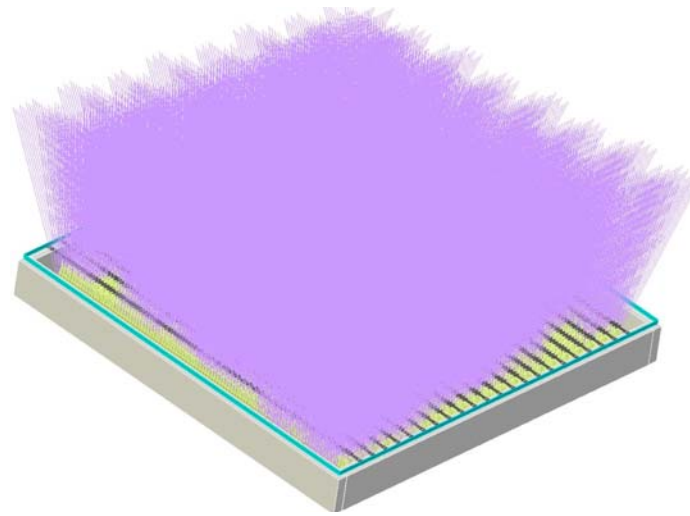
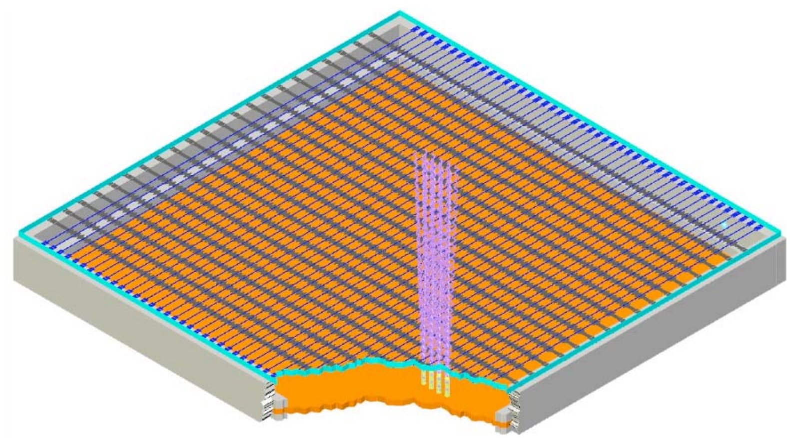
Plain & Pixilated

- **Plain FPXS**
  - whole cathode array on
  - can use hot filament or cold cathode arrays
  - large panels or groups of panels
  - spread power across entire anode
  - cathode current density relatively low
  - mainly sterilization
  - radiation source & sterilization target areas the same
  - panels on both sides provides self - shielding



- **Pixilated DAXS**
  - cold cathode arrays
  - electronically address small groups to make Xel
  - microseconds
  - panels replace tube on gantry
  - fast addressing
  - stationary CT
    - others: GE, Siemens, Philips, Xintek
  - formidable current density requirements



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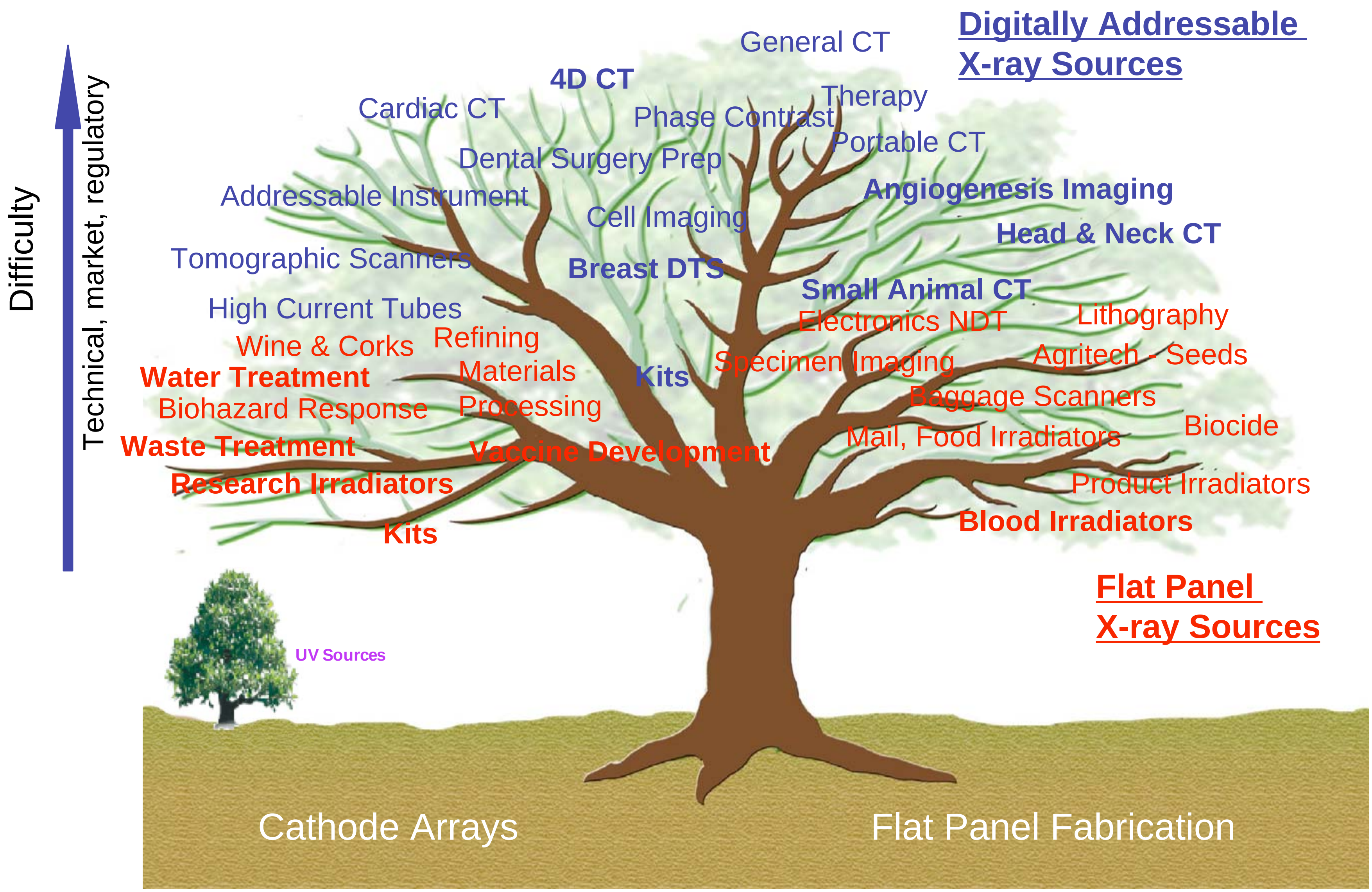
Platform Technology



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Imaging Applications

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- **DAXS better than a tube?**
  - not every imaging application
  - main advantages: speed, compactness
- **Small Animal CT**
  - small animal in vivo imaging - rapidly growing market: mouse models, mouse genome
  - better micro-CT systems needed
  - need speed to keep up with mouse heart rate (near 600 bps), better cardiovascular images
  - small spot size, higher resolution
- **Breast Tomosynthesis, Breast CT**
  - breast DTS possibly way to improve accuracy of mammograms
  - DTS systems now use linear transport of tube
  - avoid motion blurring, obtain 2D blurring of out of focus objects
  - full breast CT require compact, stationary system
- **Portable CT**
  - small system for battlefield, emergency medicine
- **Angiogenesis Imaging**
  - stationary, high speed system
- **Phase Contrast Imaging**
  - need very high resolution, monochromatic source

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Cathode Requirements

Model	Width	Length	Max Va	Max mA	Pa	Duty Cycle	Spot Width	Spot Area	Applications	Cathode Current Density	Anode Power Density	Local Power Density
	cm	cm	kV	mA	kW		mm	mm^2		A/cm^2	W/cm^2	W/pixel
FPXS												
F10X/100/1	10	10	100	10	1	1			kits	0.0001	10	
F1030/100/05	10	30	100	5	0.5	1			SCBI	1.67E-05	1.67	
F1030/100/3	10	30	100	30	3	1			small sterilization	0.0001	10	
F50X/150/6	50	50	150	40	6	1			panoramic sterilization	0.000016	2.4	
F50100/100/1	50	100	100	10	1	1			baggage scanner	0.000002	0.2	
F10X/125/1.25	10	10	125	10	1.25	1			instruments	0.0001	12.5	
F100X/150/7.5	100	100	150	50	7.5	1			panoramic sterilization	0.000005	0.75	
DAXS												
D10X/100/10/02	10	10	100	10	1	0.03	0.2	0.04	kits	25	0.3	30
D10X/100/1	10	10	100	20	2	0.03	1	1	kits	2	0.6	60
D10X/125/05/01	10	10	125	0.5	0.0625	0.03	0.1	0.01	PCB NDT	5	0.01875	1.875
D1025/80/30/03	10	25	80	30	2.4	0.03	0.3	0.09	breast DTS	33	0.288	72
D1530/100/30/1	15	30	100	30	3	0.03	1	1	portable CT	3	0.2	90
D1025/80/1/005	10	25	80	1	0.080	0.03	0.05	0.0025	small animal	40	0.0096	2.4
D5050/125/150/1	50	50	160	30	4.8	0.03	1.2	1.44	general CT, cardiac	2	0.0576	144
UV-Panels												
UVCP-5050-10-2-G	50	50	10	37500	375	0.01			air purification	0.015	1.5	
UVAP-5050-10-2-G	50	50	10	50000	500	0.01			epoxy curing	0.02	2	
HCXT	15	dia	150	3000	450	0.002	1.2	1.44	HD tubes	208	5.10	900

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Cold Cathodes

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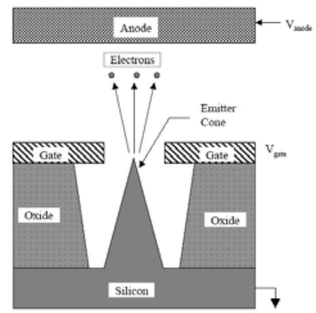
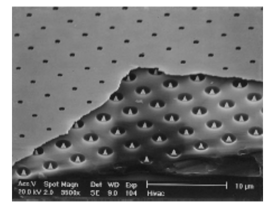
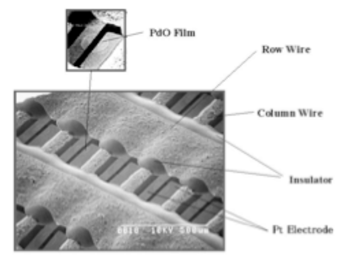
A Chinese Menu

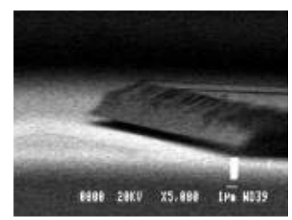
	Tip & Tube Arrays	Flat/Surface	Edge Emitter
Metal			
Mo	Spindt tips, Futaba	High energy; tubes	Many demos; unstable
W	Single tips for SEM	High energy; tubes	Many demos; unstable
Metal particles		Canon/Toshiba SCE a hybrid; also uses carbon	
Noble metals	Nanotubes, university		SMD
Metal Oxides	Nanotubes, university		
MIM		Several demos; Japan	
Semiconductor			
Si	Historical, thinnest		SMD, Koreans
GaAs	NRL, HFI demos		SMD; stability issues
GaN	UCSB, KIST demos	HFI demos	SMD; excellent results
Metal tipped	Many demos		NCSU
Coated, carbide, etc.	Several demos		SMD for NASA
Transistor-controlled	Several demos		
Nanoparticle		Matsushita, others	SMD
Carbon			
Graphitic	Some demos	Demos; chunks emit	SMD
Carbon velvet	AFRL; explosive emission		
Tetrahedral		Cambridge, others	
Diamond-like	Extreme, Vanderbilt, etc	MCC/SIDT, others	SMD, Vanderbilt
Diamond	Extreme, Vanderbilt, etc	Many demos	Vanderbilt, SMD
Particles	Coatings	Russians, others	Coatings possible
Carbon Nanotube	Xintek, many others	Pastes, Samsung	SMD/NRL, GE
CNT Variants	CNT pearls, teepees	Graphene nano-sheets	SMD/NRL
Nanostructed	SMD		SMD

Impractical/NA | Possibility | Problematic | Laboratory | Pilot | Production









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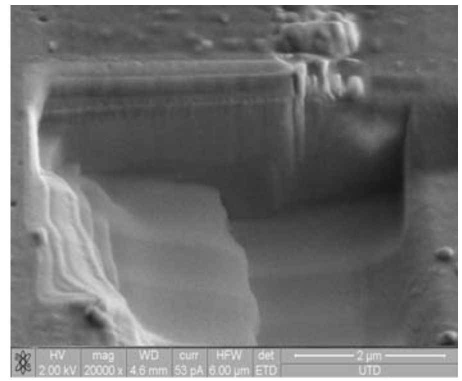
Stellarray Cold Cathodes

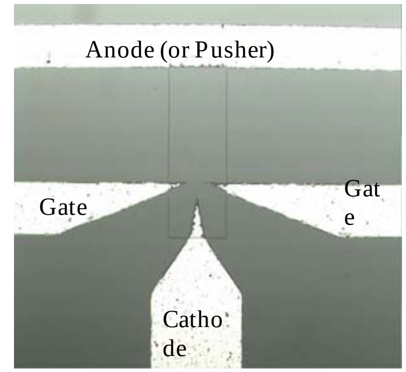
- **Lateral Edge Emitters**
  - easy to pattern
  - enhancement features through deposition
  - good for circuit, large arrays
  - incorporate ballast resistors for individual tips
  - drawbacks: leakage, density

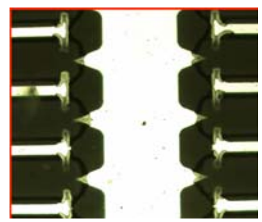
- **Lateral Tip Emitters**
  - process independence from materials
  - “nano-layered” emitters, carbon, metals
  - getting up to 200 μA/tip
  - arrays: goal of 0.013 mA/cm^2, got 1.2 mA/cm^2

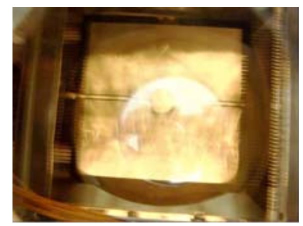
- **High Density Lateral Tip Emitters**
  - shrink x and y
  - add stacks of edges to increase z
  - gates in closer for extraction <300V

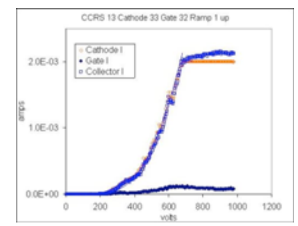
- **Pick & Place Option**
  - fab pixel die on wafer, dice, pick, place
  - finer design rules, KGD

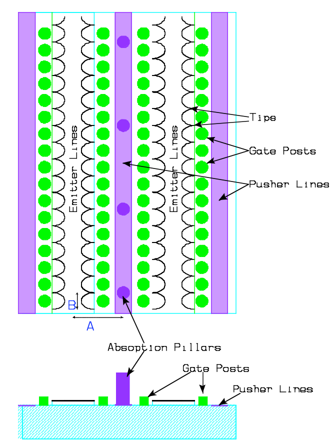


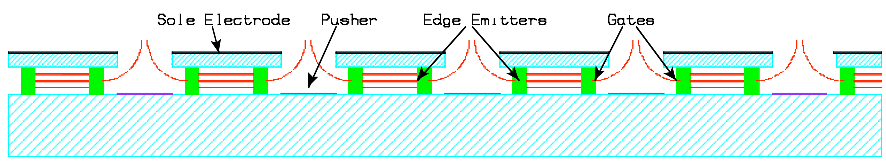












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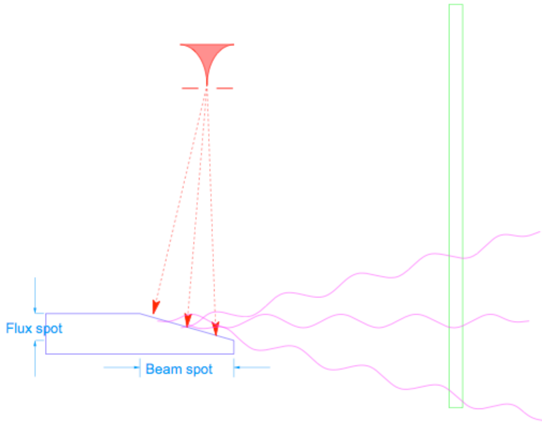
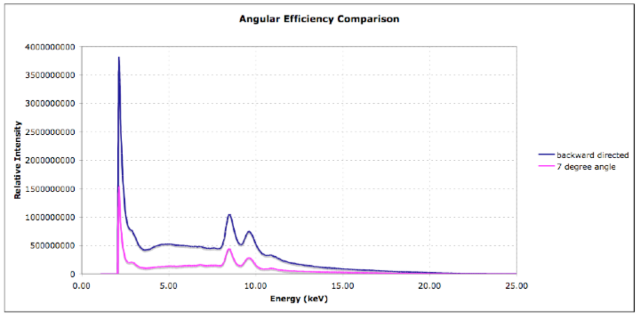
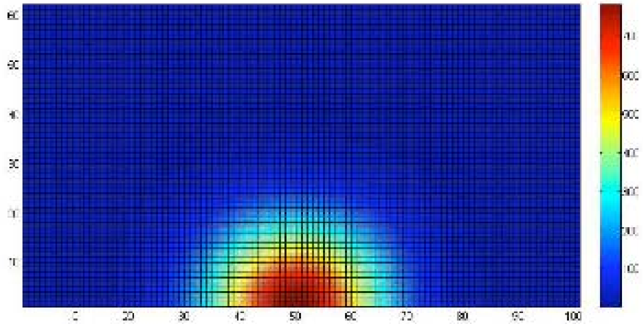
Panel Issues

- **Efficiency**
  - lose leverage of angled source
  - gain loss of heel effect
- **Cooling**
  - give up leverage of angled source
  - can't rotate anode
  - modeling shows we could melt W/Cu anode in SACT
  - coating W/Cu target with W
- **Beam Focusing**
  - testing disk pixel focusing now
  - will probably need electrostatic focusing
- **Flux Collimation**
  - less important in small animal
  - very important in human imaging - dose
  - options are internal or external shield, holes in anode







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CT Lab

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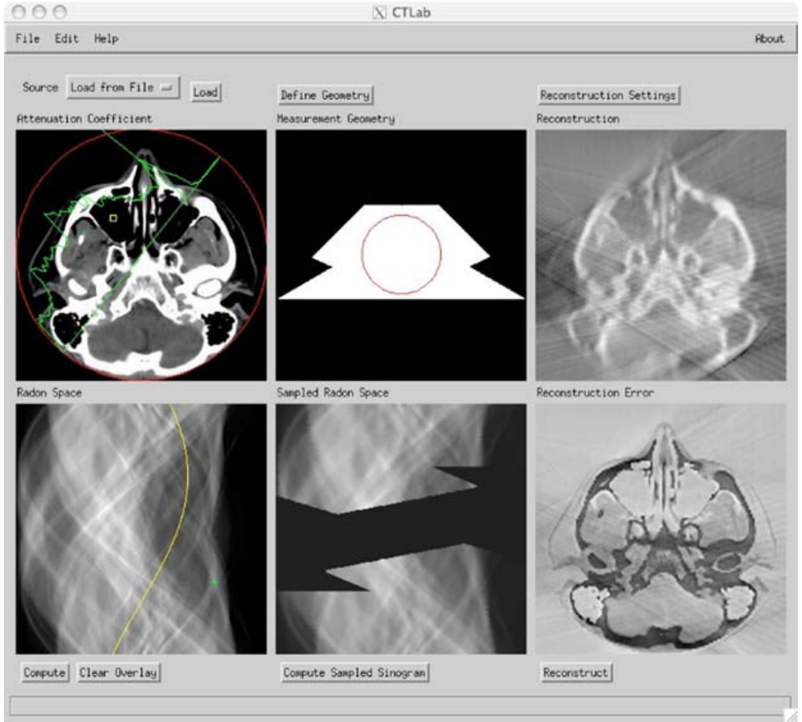
- **Imaging system design tool developed by Stellarray**
  - Produces image quality estimate from user-specified source and detector configuration
  - Written in IDL (Interactive Data Language) from ITT Visual Systems
  - Based on a demonstration module distributed with IDL
  - Distributed with an IDL virtual machine runtime system --> no license required
  - Cross-platform --> supported on Windows, MacOS, Linux, Solaris, and BSD UNIX

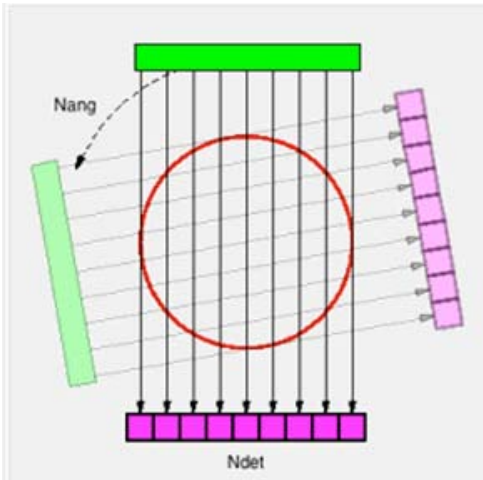
- **Used to model head & neck, breast, small animal imaging systems**

- **Freeware - download from our web site**

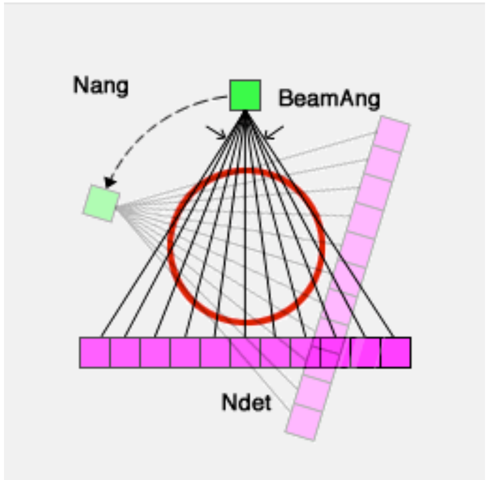


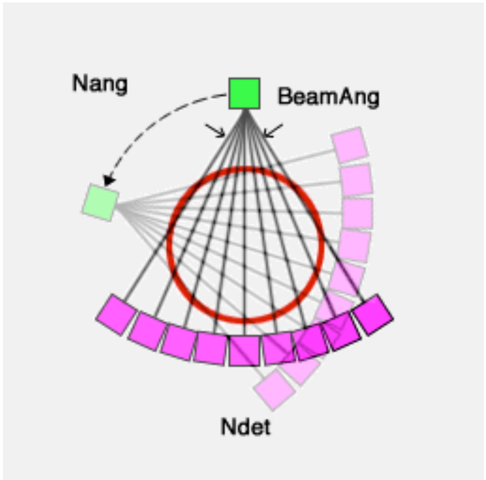
CT Lab Examples

Standard Geometries

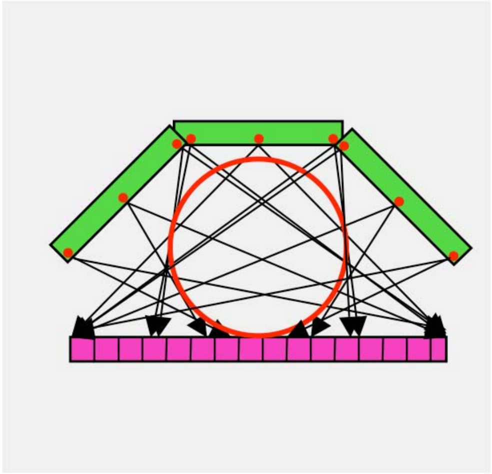


Parallel beam

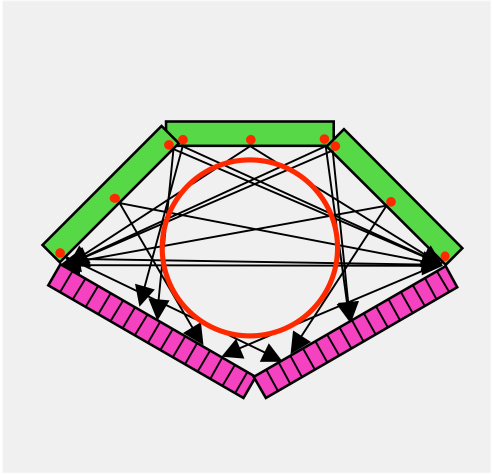




Fan Beam



Non-standard geometries as in DAXS



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