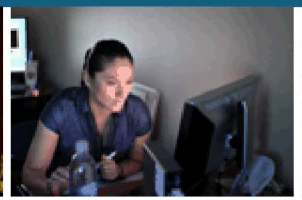
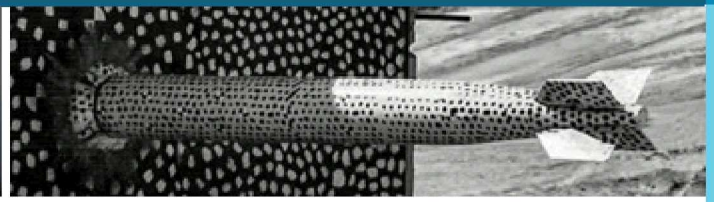
SAND2019-14777PE

Requirements for a new Image Plate Scanner Project





PRESENTED BY

Greg Dunham, December 10, 2019

National Diagnostic Working Group Meeting

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Summary

- Background
  - Funding
  - Why do we need a new scanner?
  - What do we like/not like in the current systems.
- High level requirements matrix
- Details on requirements selection
- Path forward for the project
  - Phase 1 – completion criteria
  - Phase 2 – demo
  - Phase 3 – production
- Where are we right now?

Who is paying for this new scanner?

- SNL is taking lead on getting quotes etc.
- Process current in RFQ stage
- Joint effort with funding contributions expected from Z, LLE, and the NIF.

Is there a need for a new IP scanner?

- All IP scanners currently in use at the HED facilities are no longer supported by industry.
- Commercially available scanners do not meet data quality or scan speed requirements.
- Attempts to get industry to focus on our needs have fallen short for nearly a decade.
- Issues remain:
  - Fixed pattern noise
  - Electronic saturation
  - Occasional drop out – Dan will provide graphic of drop out occurrence.

Current scanner capabilities

Likes

- Magnetic backed flatbed tray for loading IP into scanner
- Scan speed of FLA 7000
- High resolution of DITABIS Super Micron
- Tunable gain and laser power on DITABIS
- Tunable laser focus on DITABIS
- Output in familiar PSL units for Typhoon 9500 and Fuji FLA 7000

Dislikes

- Use of templates to load drum scanners
- Slow scan speed of Typhoon 9500
- Fixed pattern noise of Typhoon 9500
- Non-standard output image file formats for DITABIS and GE Typhoon FLA 7000
- Bleeding issue with FLA 7000 scanner
- Removal of sensitivity setting for FLA 7000 forces calibration against C-14 standard to determine equivalent sensitivity vs. PMT voltage settings.

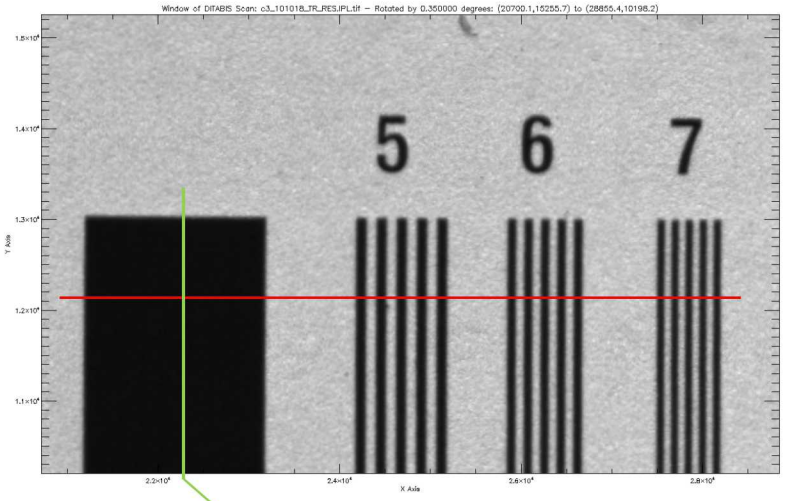
Major design considerations

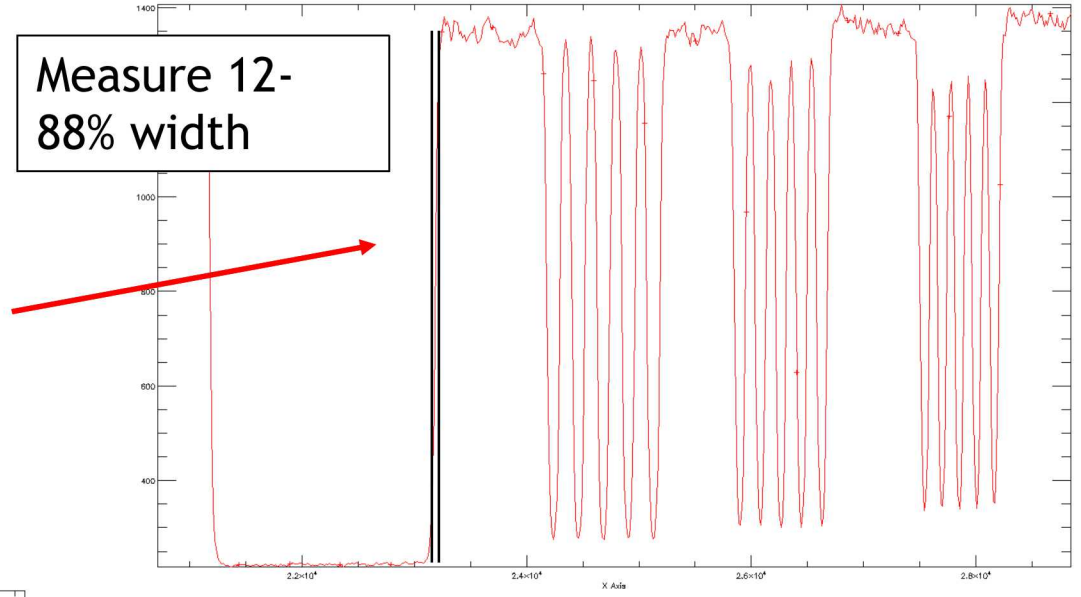
- Maximize scanner throughput
  - Increase scanning speed
  - Increasing dynamic range of a single scanned image
    - Utilize multiple PMT's or other signal gain mechanism
  - Signal processing: Increase saturation level electronically (bit depth, potential gain)?
- Maximize image quality by careful selection of a laser system
  - Laser must be tunable in power
  - Laser system focusing: IP types have different thicknesses which changes the required focal length.
  - Trade-off between laser power, focus and spot size affects penetration depth into the IP, sensitivity, and resolution.
- Light collection system
- Gain mechanism
  - PMT, multiple PMT's, APD's, or other gain mechanism.
- System architecture
  - What rotates? What moves?

Requirements for a new image plate scanner

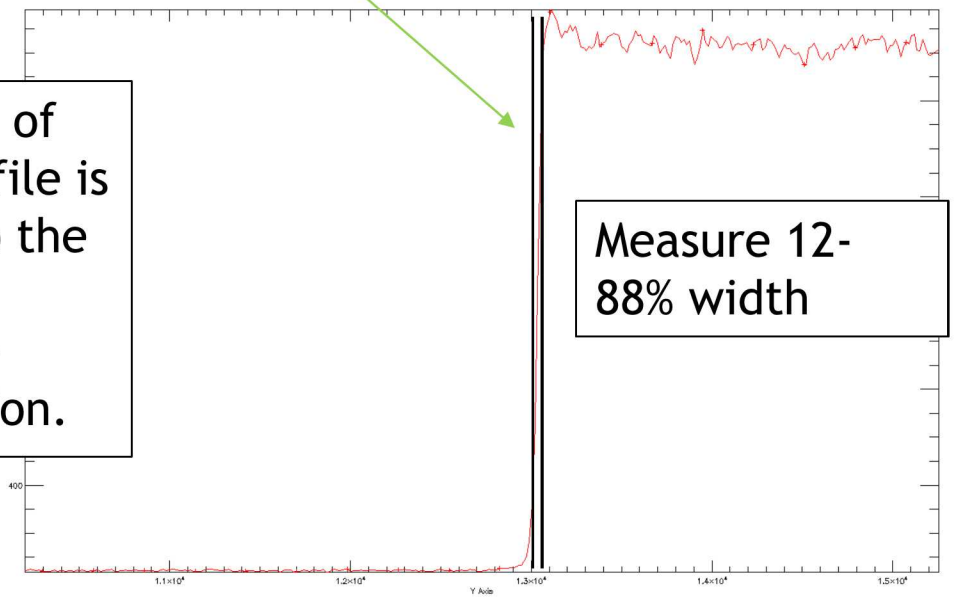
Attribute	Desired	Required	Comment
Resolution	≤ 50 mm	≤ 70 mm	As measured by an edge spread function on TR IP
Dynamic Range	$>10^7$	$>10^5$	Maximize dynamic range
IP size	20cm x 40 cm	20 cm x 25 cm	Standard size sheets
IP Type	Fuji TR, MS, SR	Fuji TR, MS, SR	COTS item
Scan speed	~20 μsec/mm	~20 μsec/mm	Comparable to speed of existing systems

Resolution from Line Spread Function





Measure 12-88% width



Measure 12-88% width

12-88% width of the edge profile is equivalent to the FWHM of a Gaussian line spread function.

Scanner Resolution (microns)

IP Type	TR		MS	
Scan direction	Vertical	Horizontal	Vertical	Horizontal
DITABIS	52	53	248	521
Typhoon*	148	76	200	237

* Typhoon data needed to be rotated by 3.8 degrees.

Dynamic range limited to 16-bit with current scanning systems

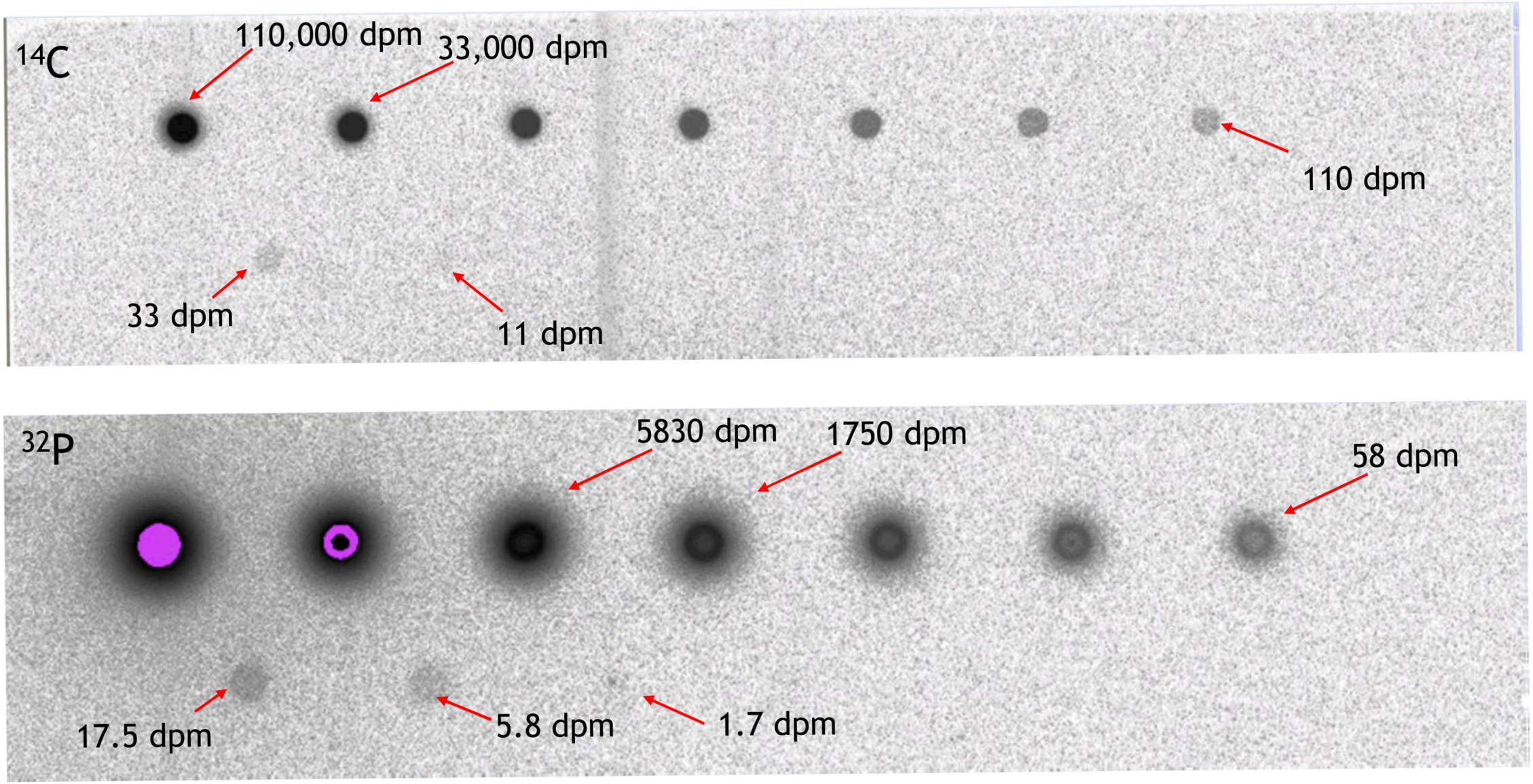
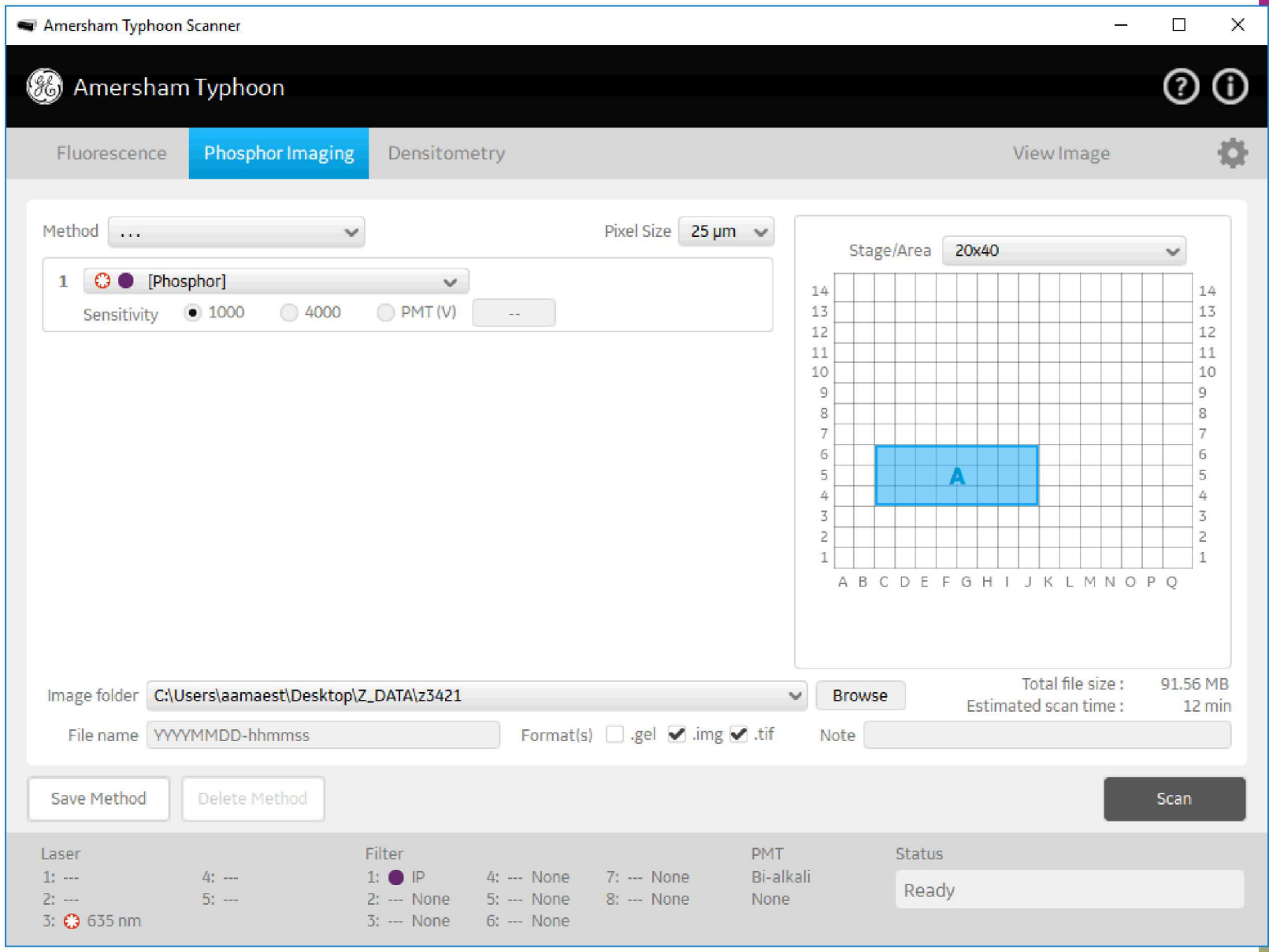


Image plate size & type

- Size of IP's to be scanned: any size ≤ commercially available IP sheets (20 cm x 40 cm)
  - scan area defined in software using a grid
  - scan area definition can be as large as 20 cm x 40 cm
  - grid should be defined on a uniform spacing in both directions on the order of 1 cm squares
  - scan regions can be defined anywhere within the grid and are not anchored to an origin



Measured Scan Speeds

Scanner	Scan area	pixel size	Total No. of pixels	Scan time	Scan rate
	(inches)	(μm)		(sec)	(μsec/pixel)
DITABIS	2.8x0.9	15	7.19E+06	253	35.20
Typhoon 9500	2x2	25	4.13E+06	272	65.88
	2x4	50	8.26E+06	315	38.14
FLA 7000	2x2	25	4.13E+06	52	12.59
	4x5	50	2.06E+07	98	4.75

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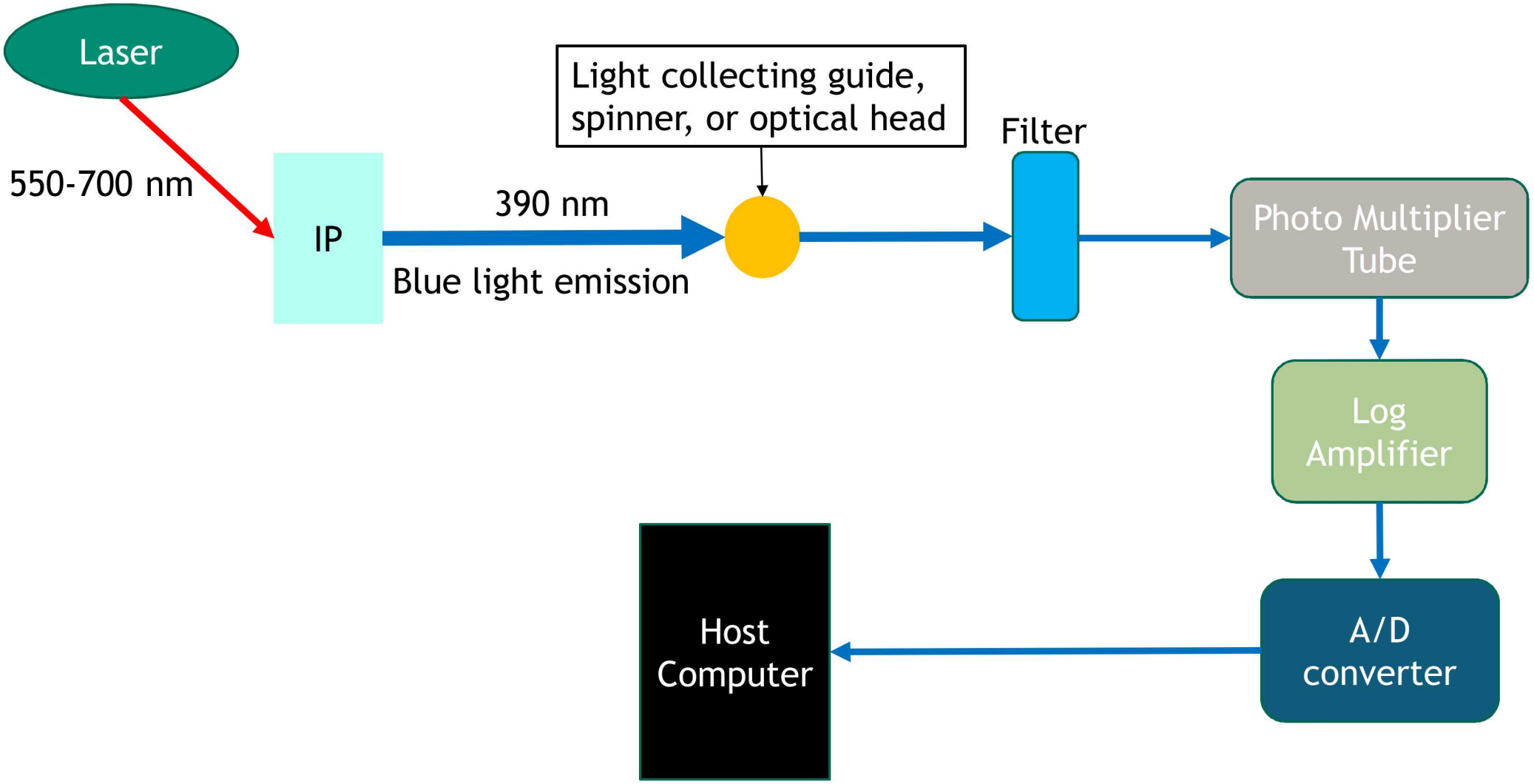
Unsupported and close to extinction

Scanning process



Scanner architecture attributes

BAS 5000 (rotating drum)	FLA 7000 (mirror/light guide)	Typhoon 9500 (flying spot)
Highest image quality	Highest scan speeds	Slower scan speed that FLA7000
Loading/unloading challenges	Bleeding/flaring in high contrast regions	Image quality lower than drum scanner
	2x worse resolution in non-scan direction	

Usage/Throughput requirements

- NIF has the highest usage - up to 6000 scans per year
  - Rescans of up to 78 times for a single plate
- LLE has the most stringent turn around time – 45 min. between shots.
  - Rescans of up to 90 times
- Z uses the highest resolution possible – set to 15 μm pixels with 52 μm resolution using TR IP
  - Rescans of 2-3 are common
  - Sensitivity is ~10^2 lower than FLA 7000

System requirements

- Able to scan any size and type of IP (MS, SR, or TR) up to 20 cm x 40 cm
- Pixel size selectable in the range of 15μm – 200μm.
- Resolution should be close to 50 μm as measured by an edge spread function.
- Laser power should be tunable to maximize sensitivity or resolution
- Laser system should allow focusing for different thickness of IP
- Dynamic range of at least 10^5 and ideally 10^7
- Scanning speed comparable to current scanners
- Operating software forward compatible with Windows operating systems as they are adopted by the various labs.

Phase 1 Goal: Conduct research to inform design choices

- Research and down select a laser system to be utilized in scanner testing. The laser shall be of order 100-150 mW output power. Output power, focus, and spot size shall be tunable. Laser wavelength should be in the range of 550-700 nm.
- An optical system that would both illuminate the image plate and collect the photo stimulated luminescence at 390 nm shall be designed utilizing PMT's, APD's, or another suitable gain medium. Design of the software to compile data from multiple signal gain media shall be included. Readout speed shall be limited to ~4 μs per pixel or slower to mitigate spatial blurring between pixels. (J A Rowlands, 2002 Phys. Med. Biol. 47 201, page R136).
- Light tight scanner housing, including the motion control system, shall be designed to package the laser, optics, and light collection system, and image plate stage for testing purposes.

Phase 1 - Deliverables

- Down selection of a stage design describing which parts move and why, to include a discussion of the criteria examined.
- Down selection of the laser and gain medium (PMT, APD's, or similar), to include a discussion of the criteria examined.
- Initial design of the optical system.
- Initial design of the motion control system.
- Initial design of the data acquisition and signal processing system, including a goal of recording PMT voltages throughout the scan.
- A report summarizing the design and demonstration of the resulting components meeting the scan system requirements.

Proposal evaluation criteria

- Technical
  - Design approach
  - Quality assurance
  - Risk mitigation
- Past performance
- Cost and value

Current status

- Request for Information posted to Sandia's Business Opportunities Website November 5-21, 2019.
- Review submittals and respond to qualified suppliers with Request for Quote.
- Review quotes and award contract for Phase 1.
- Phase 1 completion requested in 8 months after contract award.

Back up