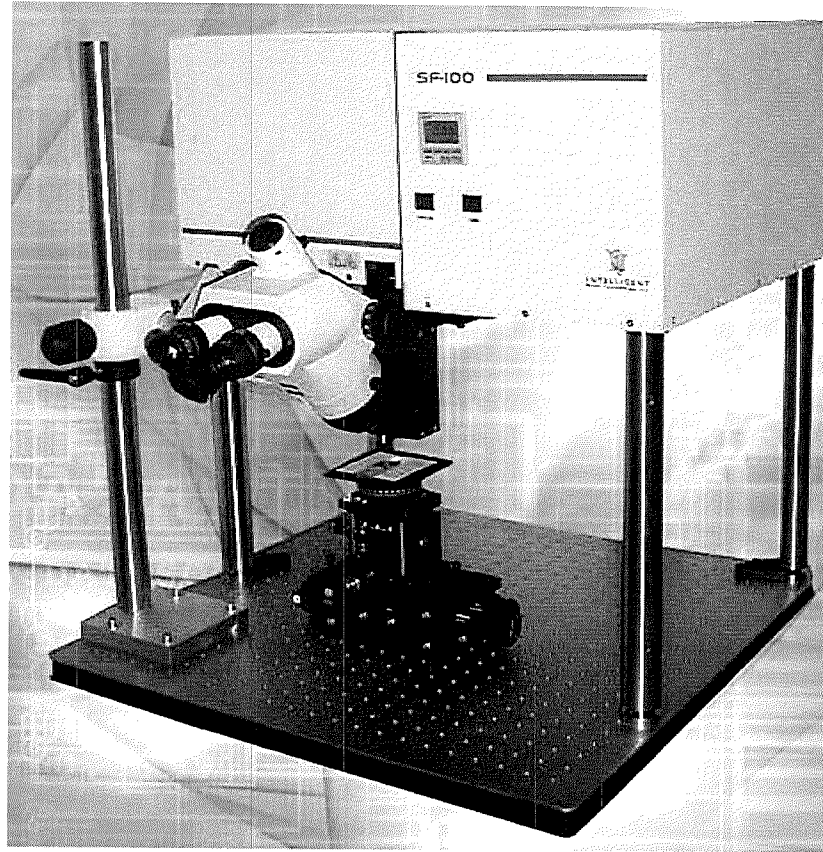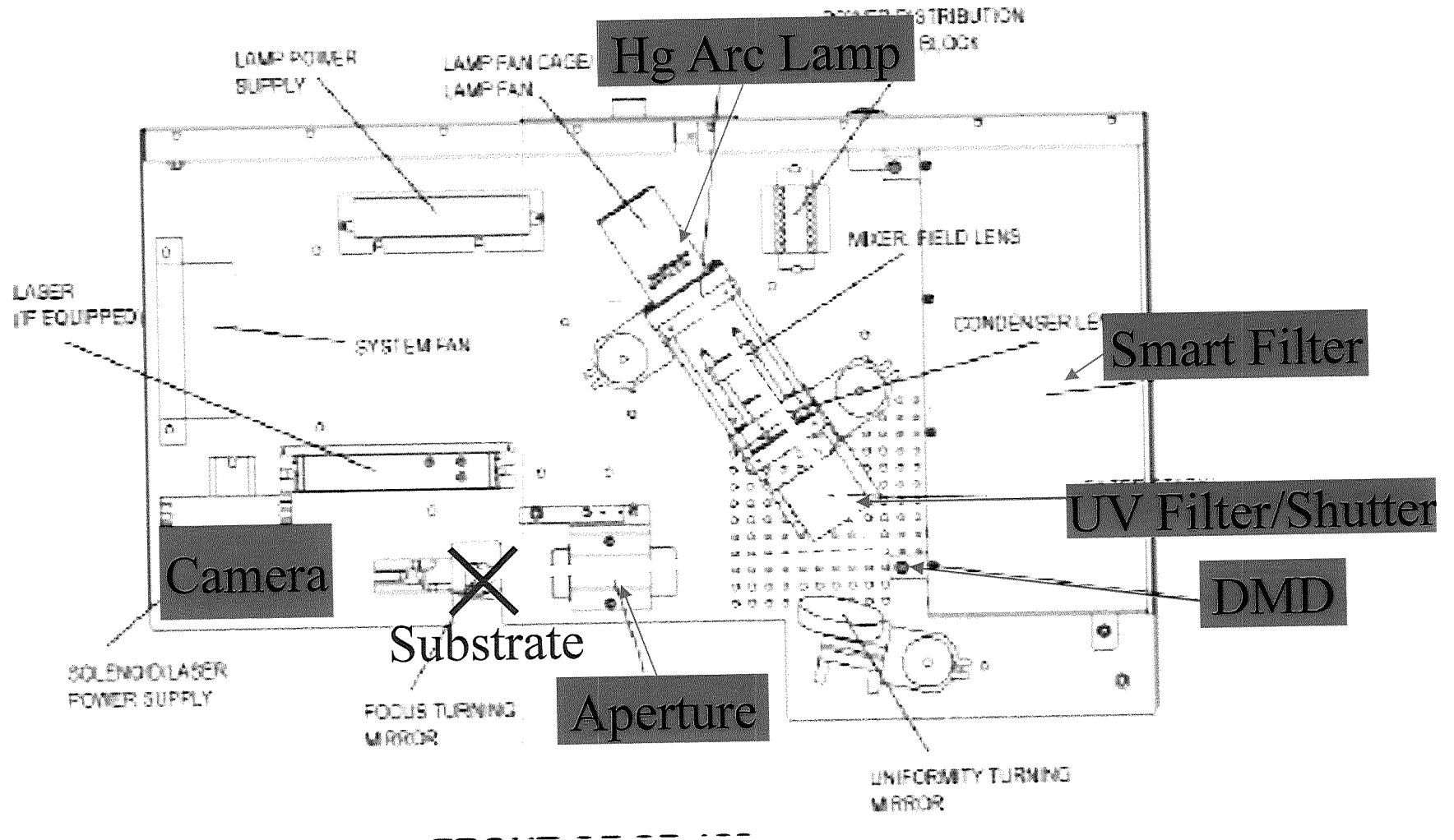# SF-100 Exposure System

Intelligent Micro Patterning


Maskless Patterning System

The Guts

LAMP POWER SUPPLY

LAMP FAN CAGE
LAMP FAN

POWER DISTRIBUTION BLOCK

Hg Arc Lamp

MIXER FIELD LENS

LASER
IF EQUIPPED

SYSTEM FAN

CONDENSER LENS

Smart Filter

UV Filter/Shutter

Camera

DMD

Substrate

SOLENOID LASER
POWER SUPPLY

FOCUS TURNING
MIRROR

**Aperture**

UNIFORMITY TURNING
MIRROR

The DMD

- Micromirror array used to generate image for maskless lithography
  - 1 cm X 1.5 cm exposure area
    - Stepper motor controlled autostage 'stitches' larger exposure areas together
      - Overlap areas greyscaled
  - Mirrors 13.75 μm square → ~15 μm minimum feature size
    - 3x reduction optics yields approx minimum resolution/features of 5 μm
  - Energy reflected from a mirror has a gaussian distribution
    - 'ghosting' algorithm can be used to correct for this
  - Aperture reduces light intensity by 5X, improves sidewall fidelity, limits gaussian energy distribution → decreases scalloping
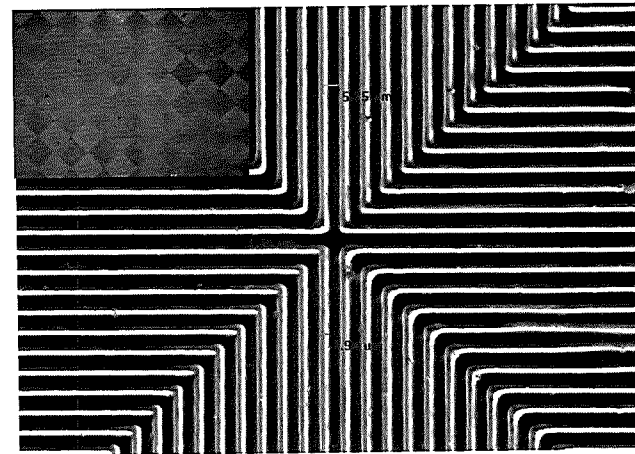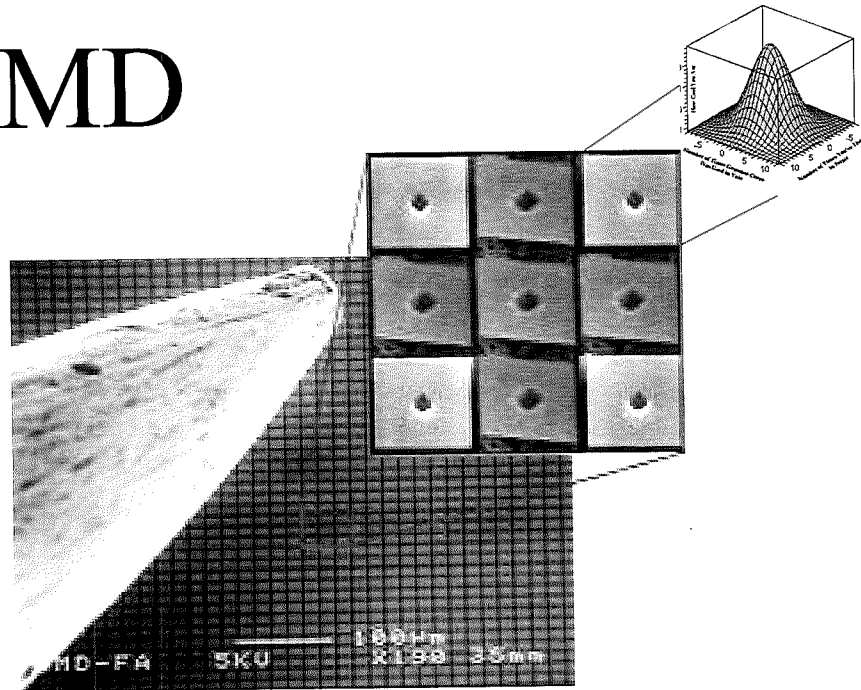
2 cm X 3 cm SU-8 field and magnified area demonstrating 5 μm features

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Consequences of the DMD

- Exposure performed in pixels
  - Bitmap files required
  - All features must be multiples of the minimum feature size (~5 0r 15 μm)
  - Curves are composed of segments
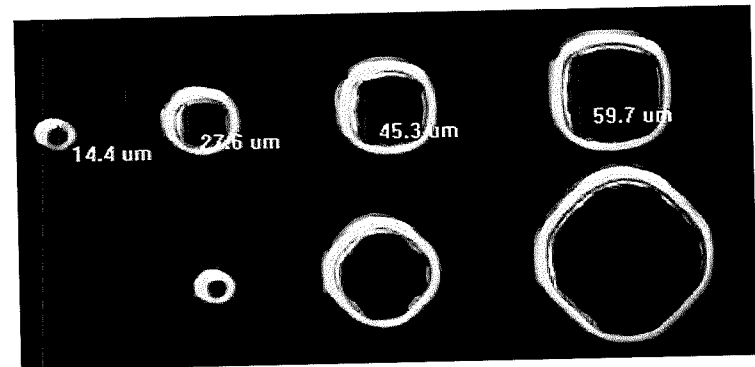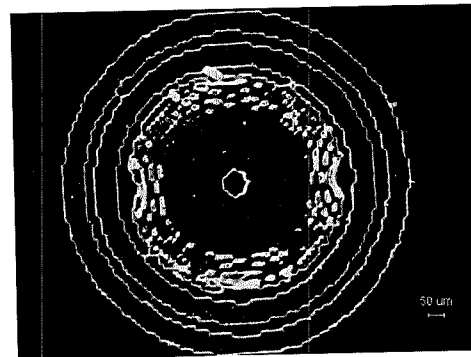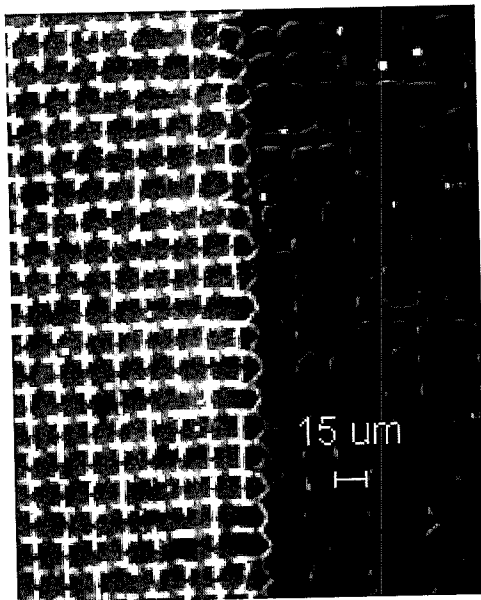
Mirror geometry evident if under-exposed, curves 'pixelated', multiples of min feature, circles approximated

Stitching

- Exposure fields larger than the exposure area (1.5 cm X 1 cm) are stitched together
  - Areas of overlap are greyscaled so that they receive approx. the same exposure energy
    - doesn't add up due to additional activation energies
  - Accuracy ± 2.5 μm (best, Random error)
    - Relative error increases with decreasing feature size

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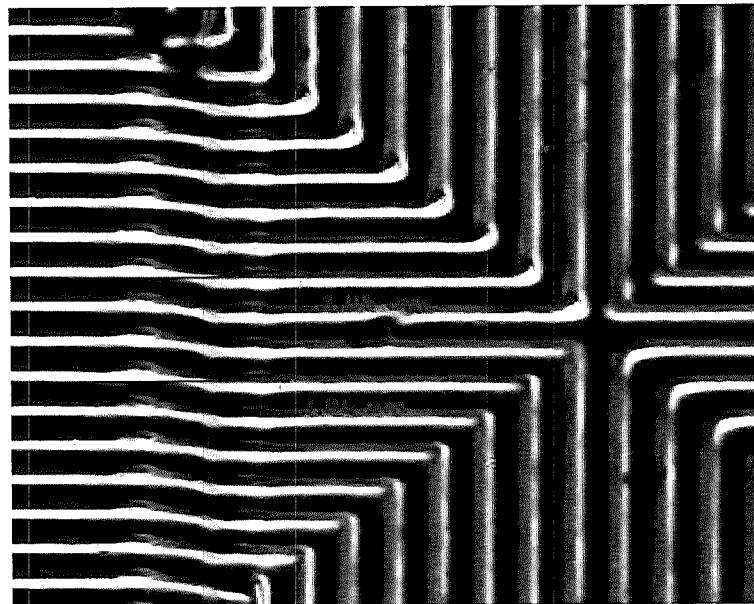
Greyscale

- 0-255 levels of Greyscale

- Mirrors are modulated to reduce energy

- Non-linear response
  - (note greyscale values used in stitching)

- Useful for rapidly determining ~ exposure time
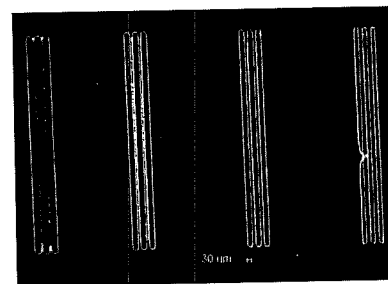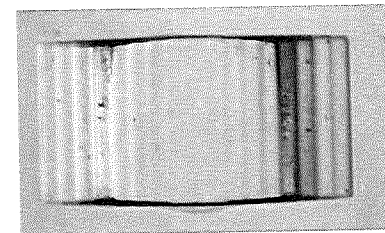
- Can be used to generate 3D topography

Greyscale Intensity Function

$y = 0.0019x^2 - 0.0364x - 0.0049$
$R^2 = 0.9963$

Exposure Intensity (mW/cm^2)

Greyscale Level
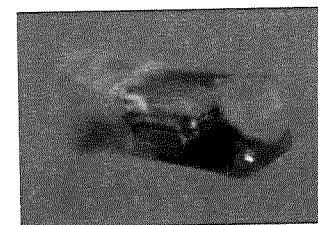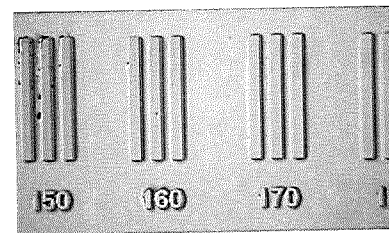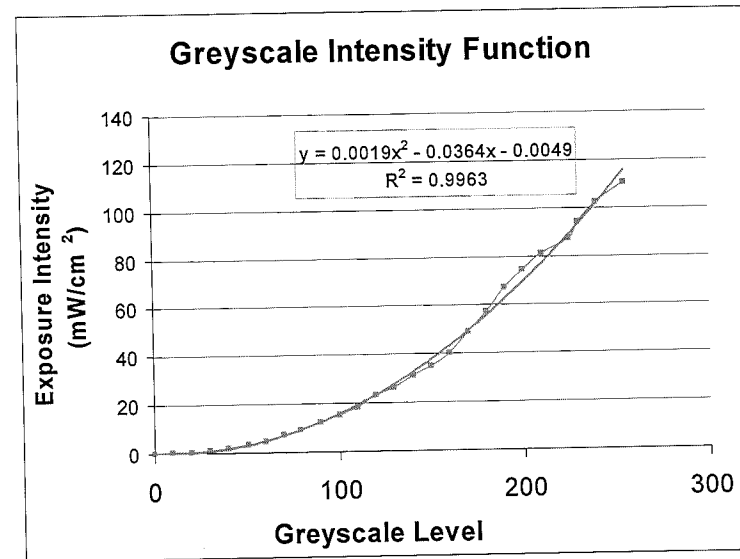
Using greyscale to evaluate different energies effect on resolution and adhesion. Use of greyscale to generate 3D topography.

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Greyscale for reducing pixelation

- Many design programs have an anti-aliasing algorithm that uses greyscale to make curves appear smoother
- Works to generate smoother curved featurs
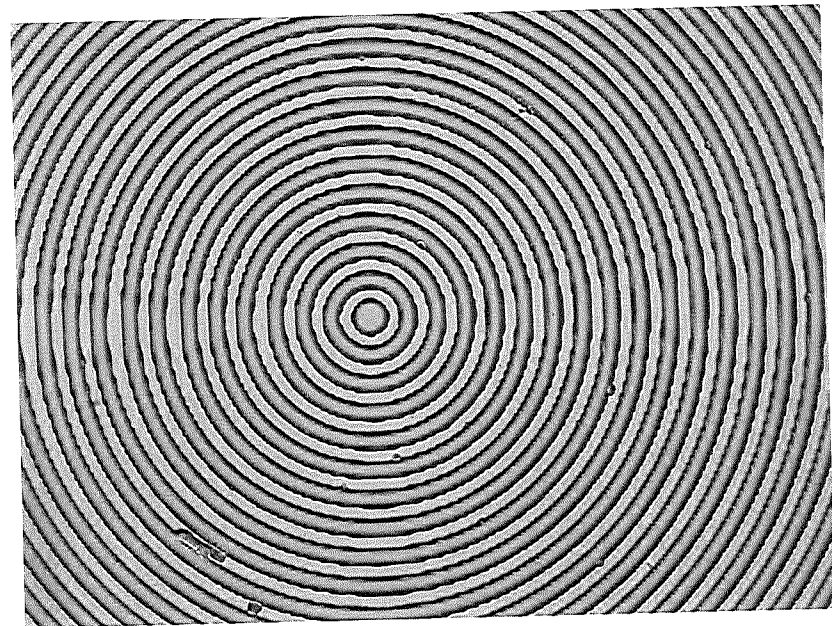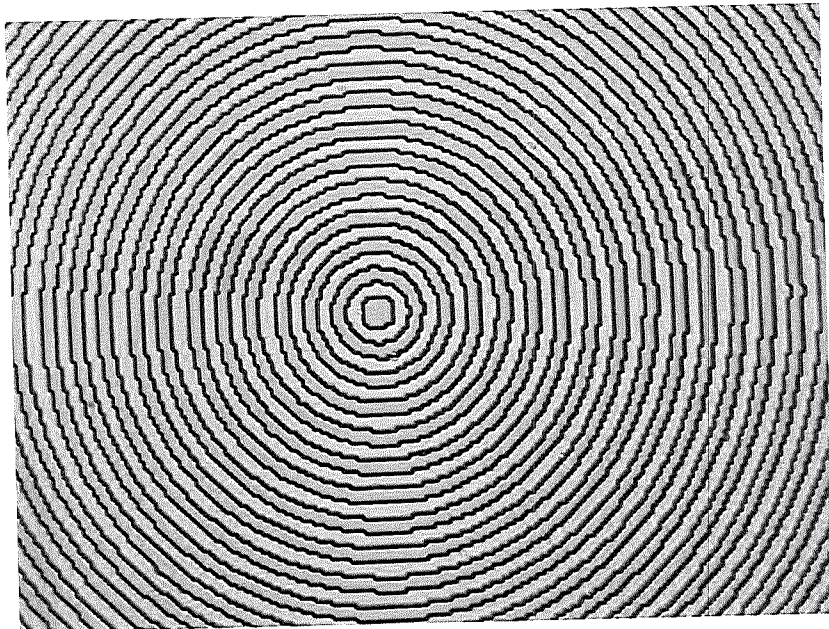
Exposure of Monochrome Bitmap vs. greyscale bitmap with anti-aliasing

Reduction Optics

- 1/3X reduction optics reduces minimum feature size to 5 μm
  - Reduces exposure area by factor of 9
  - Can reduce apparent pixelation: 9:1
  - Easily inserted and removed
    - Must refocus image
  - Stitching with reduction optics
    - Error significant for reduced features
    - Can use multilayer alignment program to include 'islands' of small features in a field of larger features
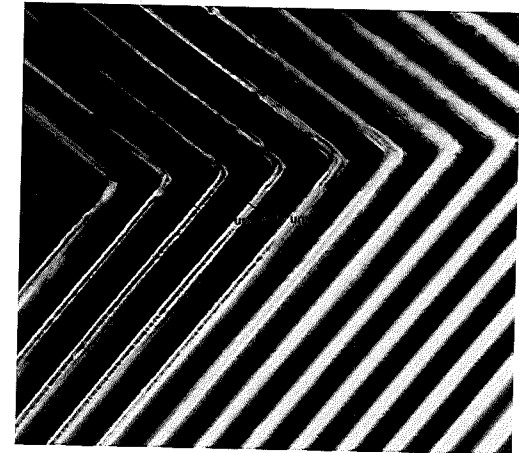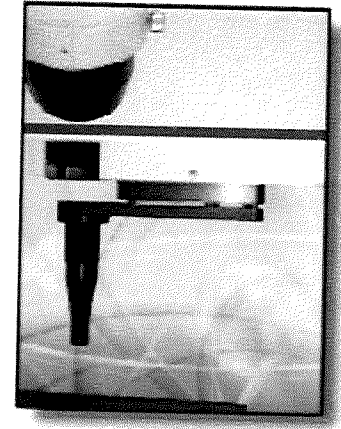
Using the Tool: Turn on Sequence

- Ensure computer is booted up
- Turn on SF-100 with switch at rear of tool
- Turn on Stage Controller
  - If the sequence is not followed, or the computer fials the autostage may move erratically and need to be turned off
- Turn on Lamp   (wait warming up for > 15 min)
- Turn system off in reverse order
  - Allow lamp to cool before turning off SF-100
  - Best to check the air exiting the left of the tool to ensure complete cooling

Using the Tool: The Lamp
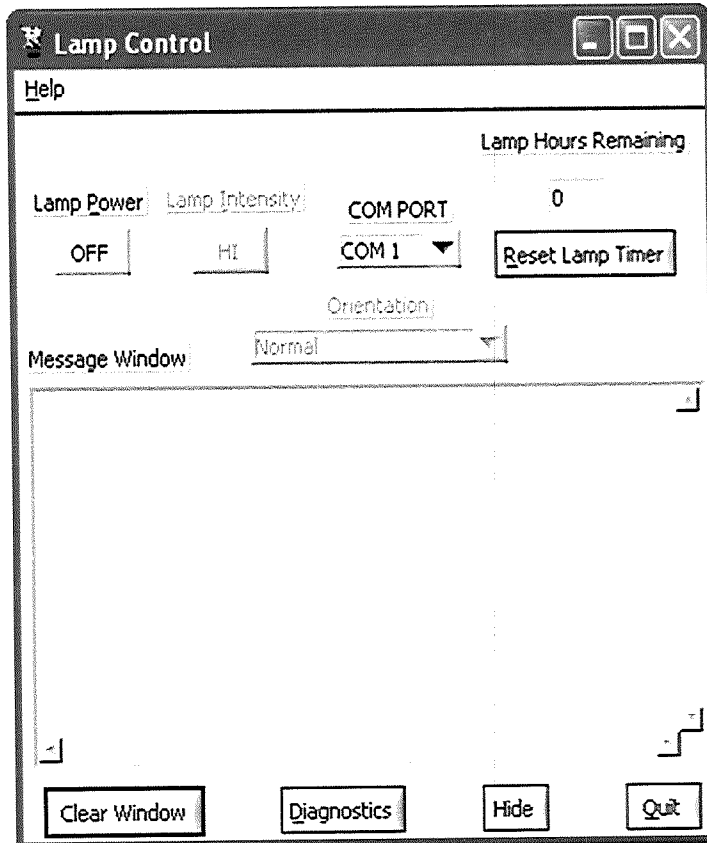
- Intensity ~20 mW/cm2

- Separate Program

- Pressing button under "Lamp Power" turns lamp on/off, text displays status

- "Low" Intensity is 90%

- Com Port 1

- Dialogue window for actions/errors

- Allow lamp to warm up 15-30 min

- Allow lamp to cool before turning off system

- Please do not reset the timer or change the orientation

- Please notify if timer is near 0 Hours

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Using the Tool: Autostage Basic

- Password for some advanced control
  - Stage speed, exposure window control, maintenance/alignment
- Click OK without enetering to use basic autostage program
- Password can be obtained if necessary
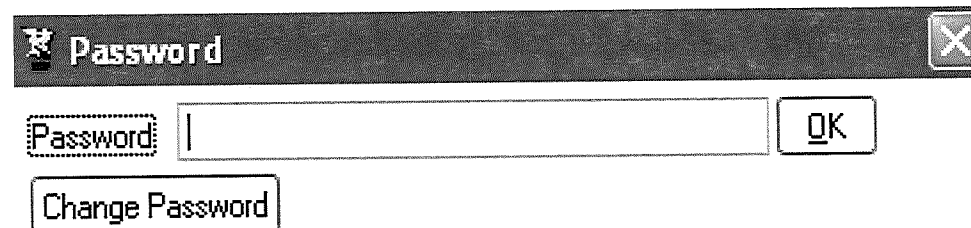
Using the Tool: Autostage Basic
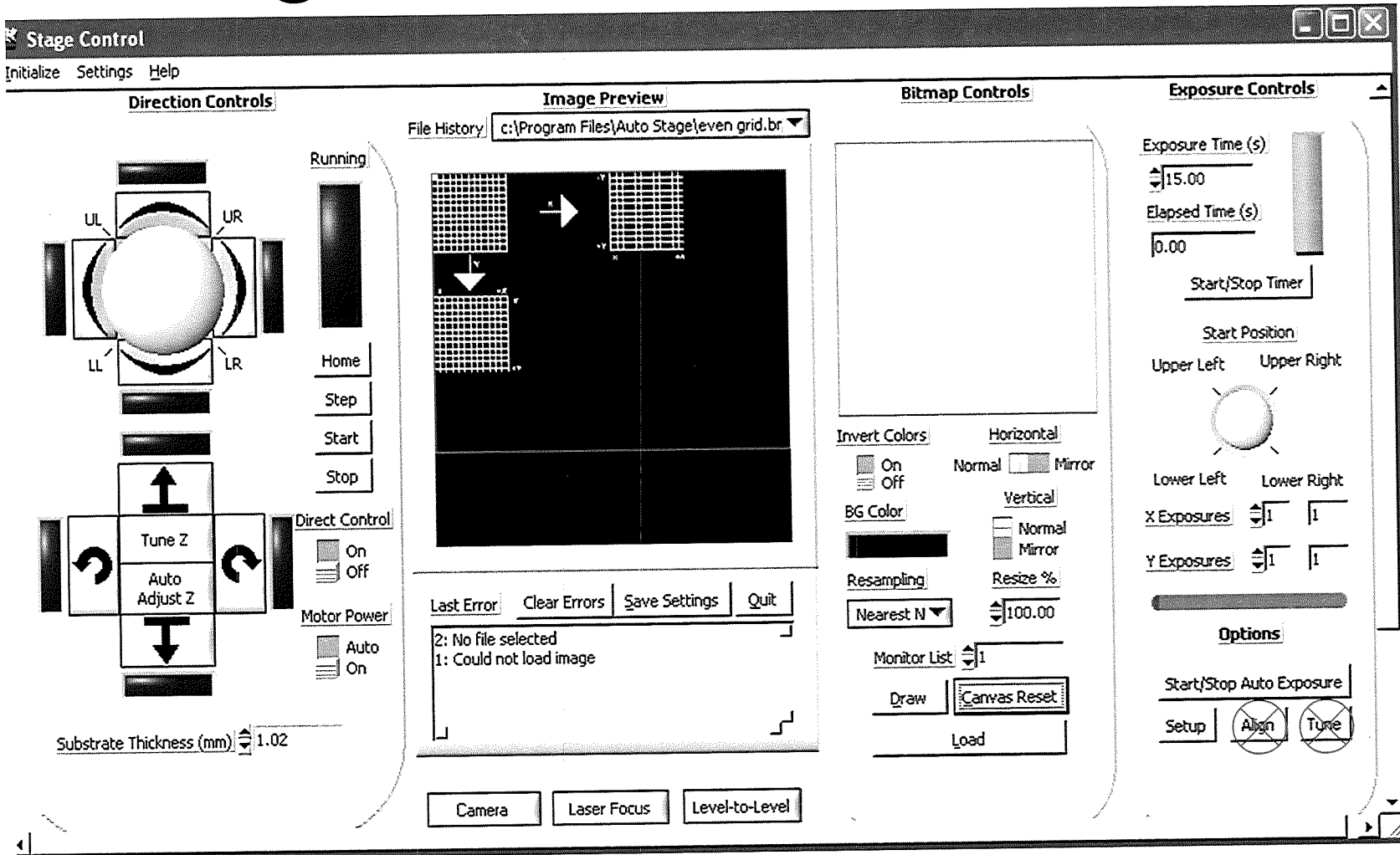
Stage control

Image control window

Exposure

Auto Focus

Links to advanced options

Stitching

Using the Tool: Autostage Advanced
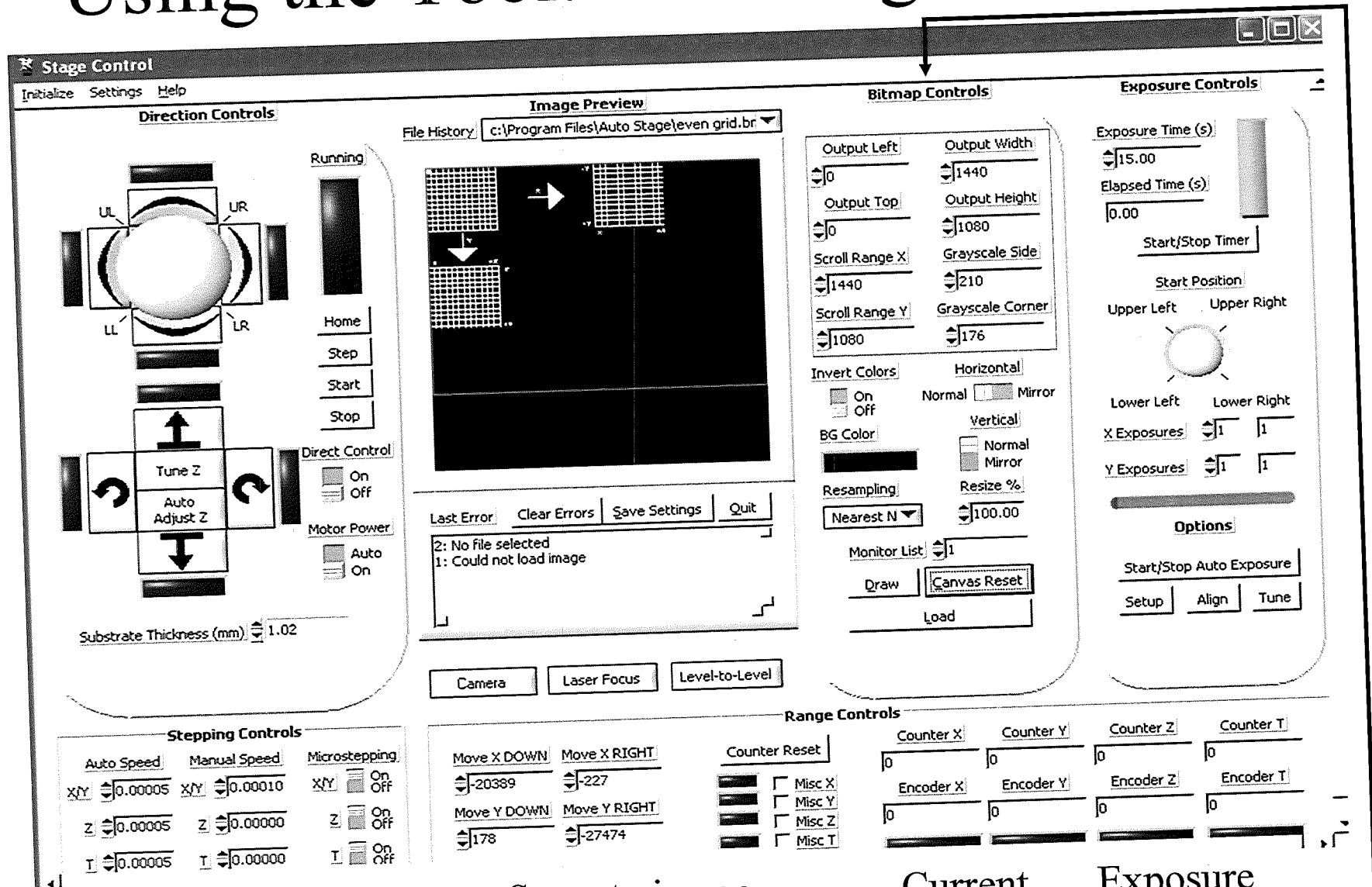
Stage speed delay value

Stage to image alignment encoder values

Current encoder values

Exposure window controls

Using the Tool Step 1: Loading the Image

- Once the lamp is warmed up and the Autostage program has been opened...
  - Load your image
    - <u>Not from desktop!</u>
  - Perform canvas reset
  - Draw to monitor 1 to check artwork
  - Draw to monitor 2 to load image into Smartfilter
    - UV Filtered Green Image
    - Clicking on the image preview will highlight the area and allow the arrow keys to be used to toggle through different portions of a large field design
  - Optics horizontally mirror image and then rotate it 90°
  - Other tools for quick image manipulation
    - Resampling algorithms for resizing
      - Resize up to 200%
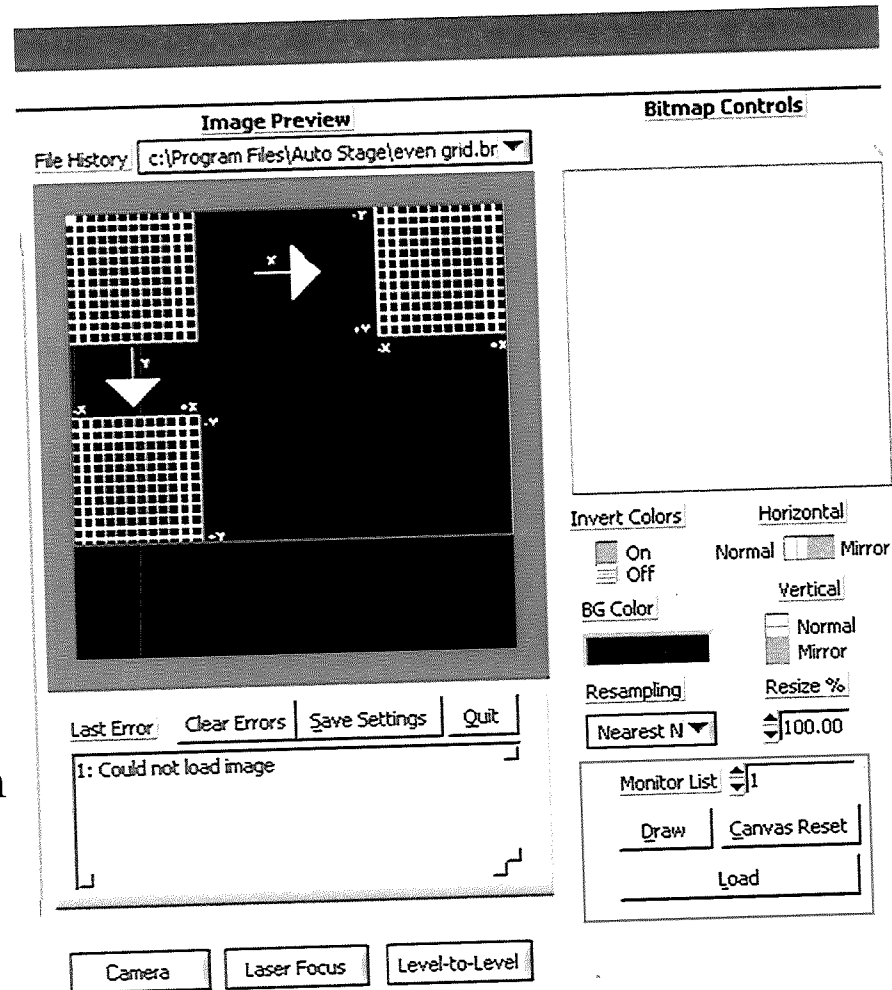
Using the Tool Step 2: Focusing the Image

- Auto Z
  - Image focused manually by tech during setup
  - Entering substrate thickness + ½ resist thickness and hitting "Auto Adjust Z" autofocuses
- Laser Focus
  - Uses laser to Autofocus image
  - Follow "Tune Laser" Steps
  - Miscalculates on reflective or transparent substrates
  - Sometimes useful to measure distances
  - Enter this menu to turn laser off, Comport 4, hit comport again to get loading box to go away
- If refocusing is needed (e.g. reduction optics usage) aperture must be removed
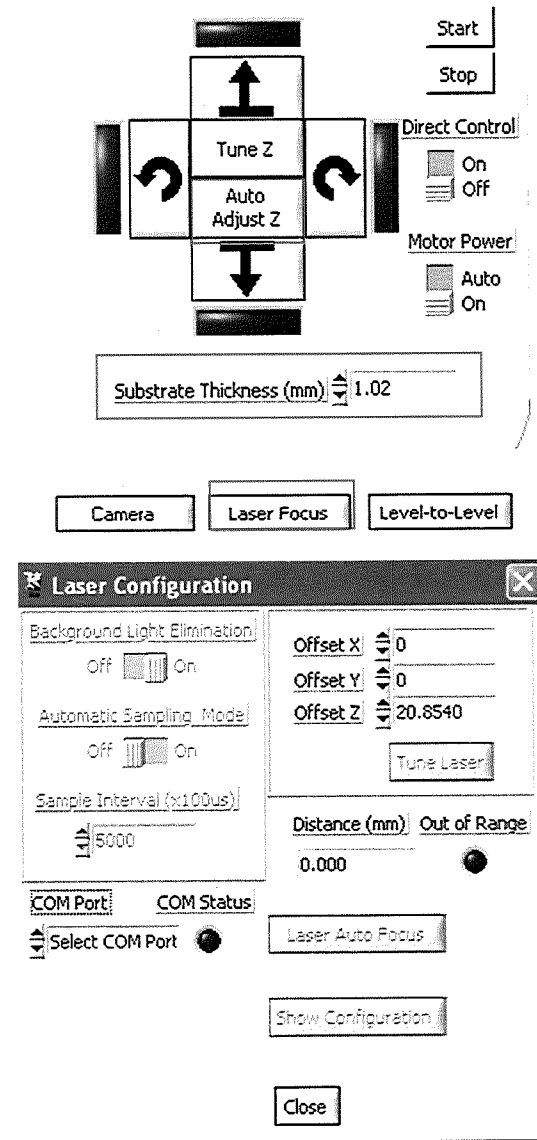
Using the Tool Step 2: Focusing the Image

- Can check focus with Motic
  - "Camera" in Autostage opens Motic
  - Generally unnecessary
    - 10 μm change in Z away from focal plane → 0.1 % error in X/Y plane
  - Depending on substrate/resist may need to play with gain/exposure to view image
    - Increased exposure reduces camera response time
    - Gamma ratio can improve contrast
    - Native resolution, can increase
    - Highlight area, Fit to Window, keep ratio for digital zooming
    - Camera 1.5X magnification, can add additional 2X for advanced operations

| Camera | Laser Focus | Level-to-Level |

Motic MCCamera 1.1

Settings

Preview
1024 x 768
2048 x 1536
1024 x 768
512 x 384

Capture Size
2048 x 1536

Pause

Adjust
Gain — 7.75
Exposure — 400.1
Sharpness ☑ — 7
Color Correction ☐ — 0
Gamma — 0.910
Auto Adjustment ☐ Auto Exposure

☐ Fit To Window   Keep Ratio

Capture   AutoCap   Video   Advanced   Help

White Balance | Cancel | ROI

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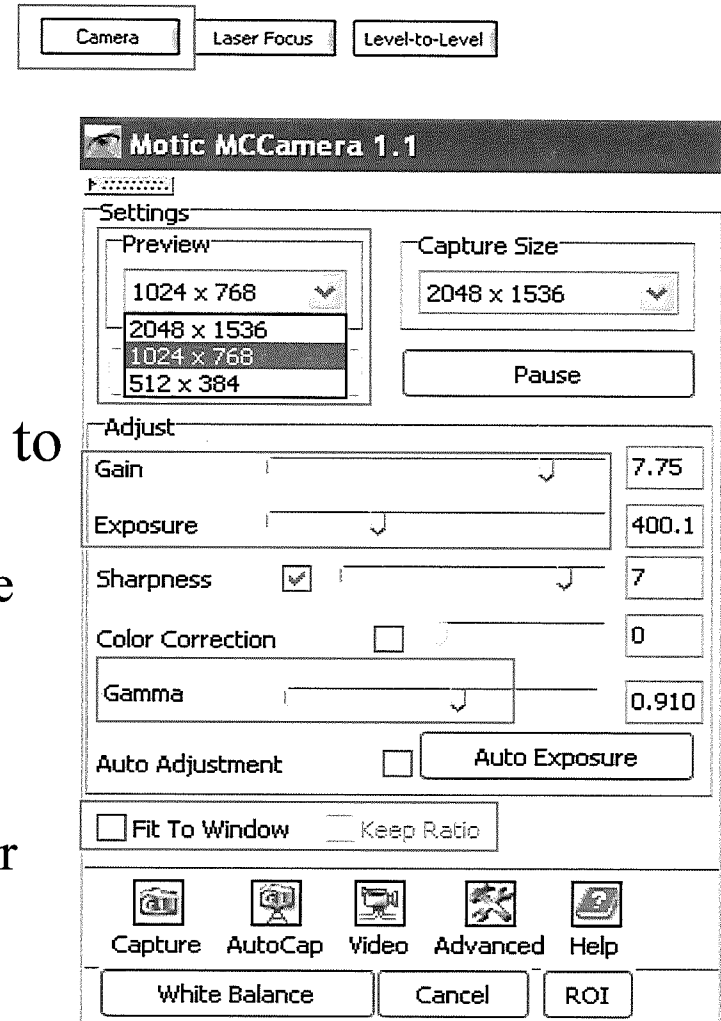
Using the Tool Step 3: Image-Substrate Relations

- Moving the Stage in X and Y
  - Important to ensure a stitched exposure will not go off substrate
  - To Place image where desired on substrate
- Vacuum chuck available
- Toggle "Direct Control" on to use Joystick, PGM control, or Arrow keys
  - Keep in mind the stage moves not the image
  - Directions can be chosen (will highlight on PGM) then "Start" & "Stop" to control stage
  - Alternatively Stage can be started and directions can be changed on the fly
  - Yellow highlight indicates stage has hit a limit
  - Shift and Home, End, arrow keys: start, stop and move the stage

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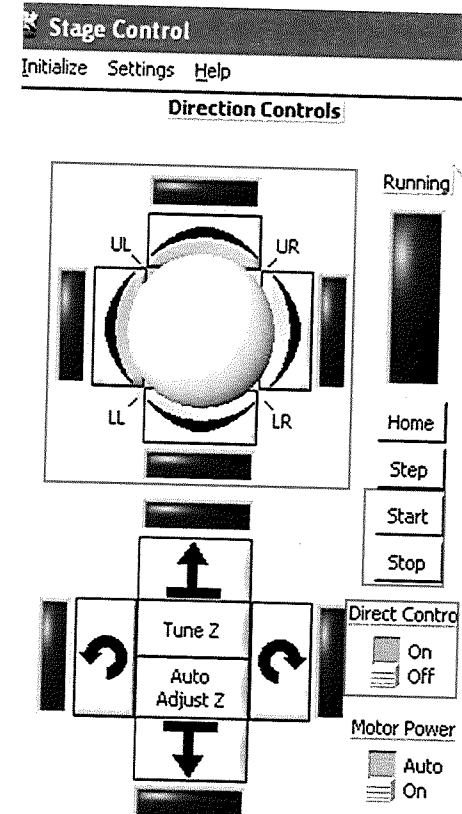
Using the Tool Step 3: Image-Substrate Relations

- Image is horizontally mirrored and rotated clockwise 90°

Image in GUI
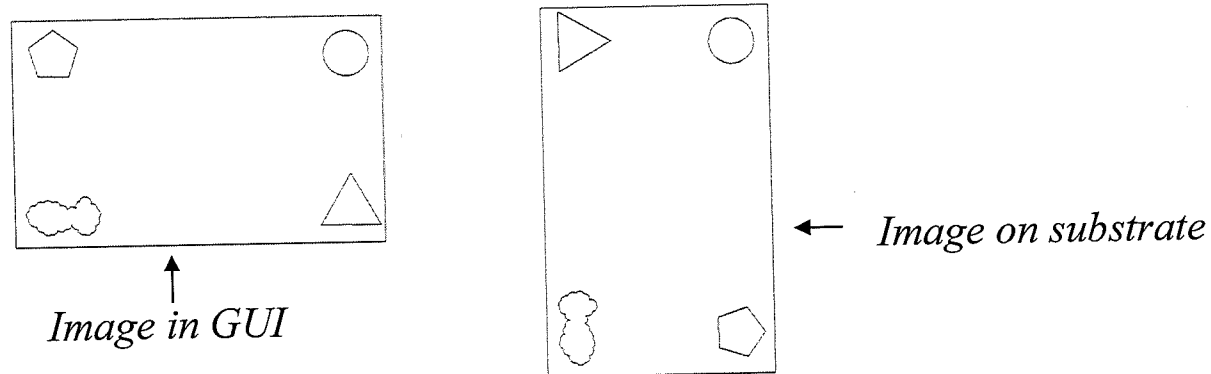
← *Image on substrate*

- Moving a single exposure window (scroll range) is useful for multiple exposures of the same image, aligning substrate for stitching, and determining image fit
  - Choose direction
  - For single scroll range directions are mirrored and rotated 90° (directions do not directly translate only for this application!!!)
  - Arrow Key map: →, moves away; ←, moves towards; ↑ moves right; ↓ moves left
  - Advanced controls allow scroll range to be changed

Using the Tool: Joystick

- To use the Joystick for Autostage control Open the logitech profiler with the W icon near the clock

- Useful when performing gross alignment

- Select "Play Stage" to open the Autostage program

Up: Rotate Lever Forward to select direction
Down: Rotate Lever Backward to select
Right: Move joystick far right to select activate trigger to start motion and again
Left: Move joystick far left to select direction
Forward: Move joystick away from user direction
Backward: Move joystick toward user
Rotate Clockwise: Rotate joystick clockwise direction
Rotate Counterclockwise: Rotate joystick counterclockwise to select direction counterclockwise to select direction

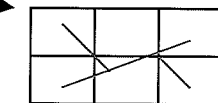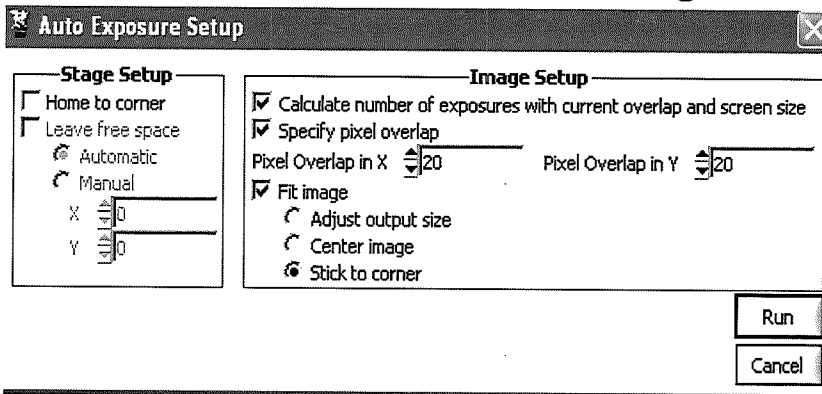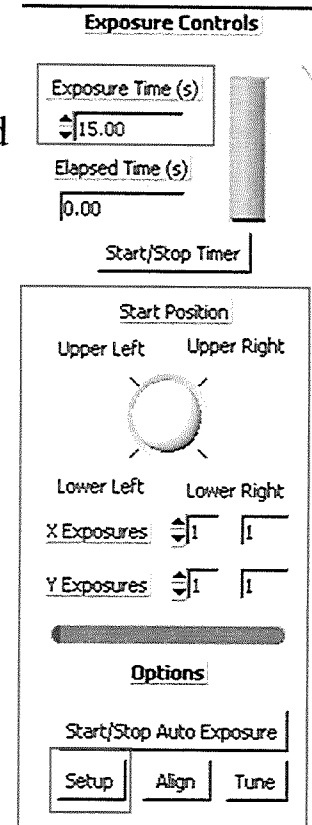# Using the Tool Step 4: Exposure; Single Shot

- Ensure lamp is warmed up and 'full of life'
- Set desired exposure time
  - 0.01 s resolution
- Press "Start/Stop Timer" to removed UV filter and start exposure
  - Note that additional time elapses to account for shutter speeds
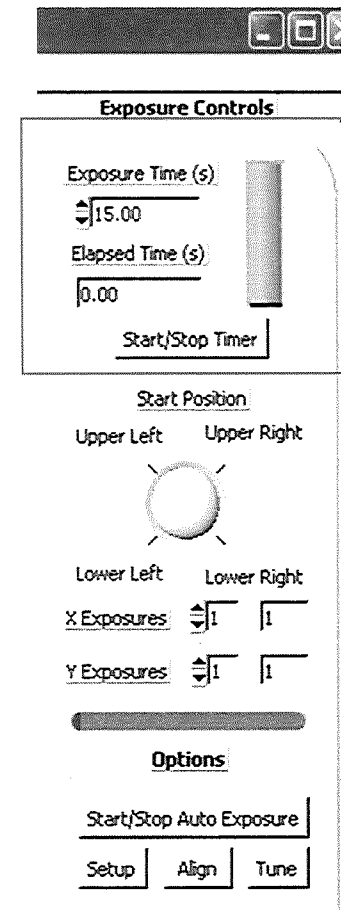
Using the Tool Step 4: Exposure; Stitching

- Larger field images are composed of multiple single shots
  - Each shot is overlapped (greyscale at overlap) and the stage moves automatically to exposure entire image
    - Moves in serpentine pattern
    - Greyscale levels controlled in bitmap controls, experimentally optimized
    - Alignment for stitching performed during system setup
- Consider image-substrate relations and check that entire image will fit on substrate/find a starting point.
- Ensure direct control is off
  - Use start position dial to control where exposure starts
  - Run setup:
    - to control exposure window placement relative to image
    - Control pixel overlap (min 4, 20 recommended)
    - Will auto calculate number of X and Y exposures
  - X and Y exposures. Grid based, e.g.

Exposure Controls

Exposure Time (s)

15.00

Elapsed Time (s)

0.00

Start/Stop Timer

Start Position

Upper Left   Upper Right

Lower Left   Lower Right

X Exposures 1 1

Y Exposures 1 1

Options

Start/Stop Auto Exposure

Setup | Align | Tune

Auto Exposure Setup

Stage Setup
- Home to corner
- Leave free space
  - Automatic
  - Manual
    - X 0
    - Y 0

Image Setup
- Calculate number of exposures with current overlap and screen size
- Specify pixel overlap
  - Pixel Overlap in X 20   Pixel Overlap in Y 20
- Fit image
  - Adjust output size
  - Center image
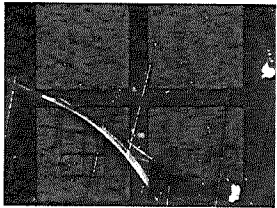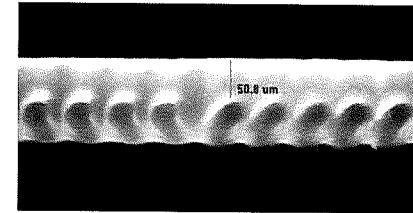 - Stick to corner

Run

Cancel

$X = 3, Y = 2$

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- Input exposure time and hit "Start/Stop Auto Exposure" to start

Multilayer Lithography

- Level-to-Level alignment Program
  - Align image to features on substrate
  - Use at least 3 fiduciary marks
    - Align image to marks using camera
    - Calculates theta offset and scale offset and corrects for them
      - Scale is for features that are not the expected size
    - Perform 3 iterations to generate low offset values

Level-to-Level

Alignment Mark Table

	X Coordinate	Y Coordinate	Scaled X	Scaled Y
Initial	720	540	720	540
Mark 1	0	0	0	0
Mark 2	0	0	0	0
Mark 3	0	0	0	0
Mark 4	0	0	0	0

Calculated
X 0
Y 0

Corrected
X 0
Y 0

Offsets
Theta (degrees) 0.000000
Scale (%) 0.000000

Display Mark   Get Corrected Values   Correct Theta
Go To Mark   Calculate Offsets   Correct Scale

Current Mark 1   Import Export Close

	X	Y	Z	T
Encoder Resolutions	-1000	1000	1250	1250

Summary for Use

- Load image
- Focus image
- Move substrate to point of exposure/ensure image will fit on substrate
- Expose
  - Determine exposure time
  - Setup stitching parameters
- Link to Manual in Help file of Autostage and on Desktop

When disconnecting Hardware Please do not disconnect DAQ card accidentally

Safely remove DAQCard-1200   6:27 PM