New Particle Counter Technology for Measuring Liquid Chemicals and Slurries in Semiconductor Manufacturing

Levitronix Conference
San Jose, CA
Feb 2009

Agenda

- Winter 2008 ITRS Update
- Current Method for Detecting Particles in Liquids
- Novel Imaging Approach
- Challenge of Slurry Measurements

ITRS Yield Enhancement Summary

- Minor updates to roadmap made in Winter 2008 meeting
- UPW:
  - Current spec's @ 50 nm particle size
- Liquid Chemicals
  - Current spec's @ 65 nm particle size
  - HF, HCl, H2O2, NH4OH, IPA, Ethylene Glycol, Post-CMP cleans
- Critical particle size now below current specifications

Winter 2008 YE9 ITRS Update	2009	2010	2011	2012	2013	2014	2015
Critical Particle Size (nm)	25	22.5	20	17.9	15.9	14.2	12.6
UPW: # of particles > 50 nm/mL	<0.3	<0.3	<0.3	<0.2	<0.2	<0.2	<0.1
UPW: # of particles > critical particle size (#/L)	100	100	100	300	200	200	200
49% HF: # of particles > 65 nm/mL	4	4	3	3	3	1	1
49% HF: # of particles > critical particle size (#/L)	70	100	100	140	200	100	140
37% HCl: # of particles > 65 nm/mL	4	4	3	3	3	1	1
37% HCl: # of particles > critical particle size (#/L)	70	100	100	140	200	100	140
30% H2O2: # of particles > 65 nm/mL	4	4	3	3	3	1	1
30% H2O2: # of particles > critical particle size (#/L)	70	100	100	140	200	100	140
29% NH4OH: # of particles > 65 nm/mL	400	400	300	300	300	100	100
29% NH4OH: # of particles > critical particle size (#/L)	7000	10000	10000	14000	20000	10000	14000
100% IPA: # of particles > 65 nm/mL	400	400	300	300	300	100	100
100% IPA: # of particles > critical particle size (#/L)	7000	10000	10000	14000	20000	10000	14000
Ethylene Glycol: # of particles > 65 nm/mL	4	4	3	3	3	1	1
Ethylene Glycol: # of particles > critical particle size (#/L)	70	100	100	140	200	100	140
Post-CMP Cleaning Chemicals: # of particles > 65 nm/mL	< 40	< 40	< 30	< 30	< 30	< 10	< 10

Challenge: Ultra Pure DI Water is VERY Clean!

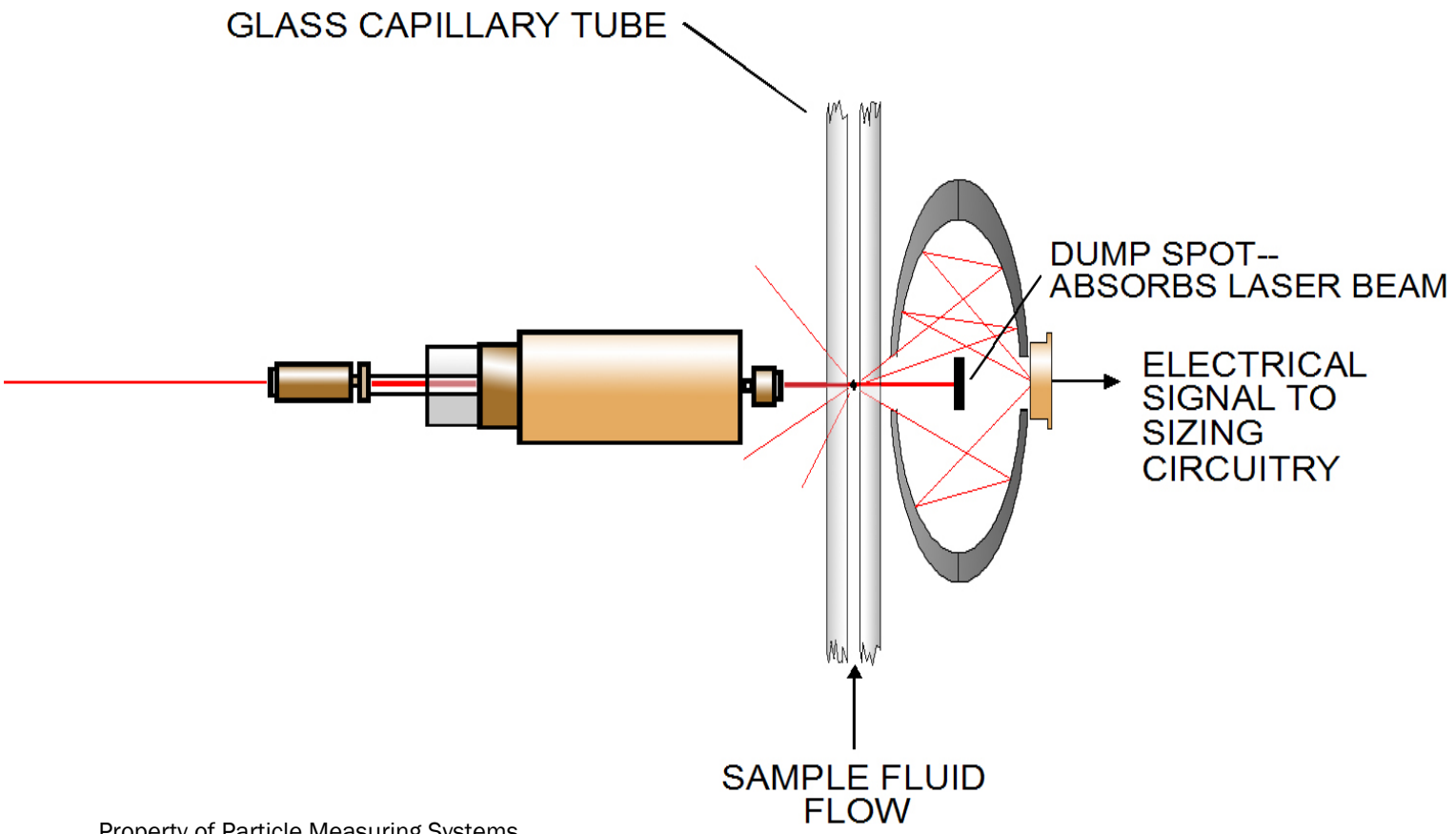
- Particle requirements most stringent in Fab
  - <0.1 PPT (particles by volume @ 200 cts per liter > 50 nm)

- NVR, metallics, other ions may exceed concentration of particles by more than 4 orders of magnitude

Traditional Methods

- Single Particle Optical Sensor (SPOS) Approach
  - Use single wavelength laser
  - Collection optics
  - Multi-element photo-detector
  - Analog-to-digital converter and processing
- How to improve instrument sensitivity
  - Smaller wavelengths
  - High laser power
  - Improved optics
  - Smaller photo-detector arrays
  - Smaller sample volume

Liquid Particle Counter



Novel Approach: NanoVision Technology™

- Use proprietary digital imaging technology
- Divide sample volume into millions of parts
- Digitize signal
  - No longer analog
- Proprietary signal processing electronics
- Proprietary signal processing software

Advantages

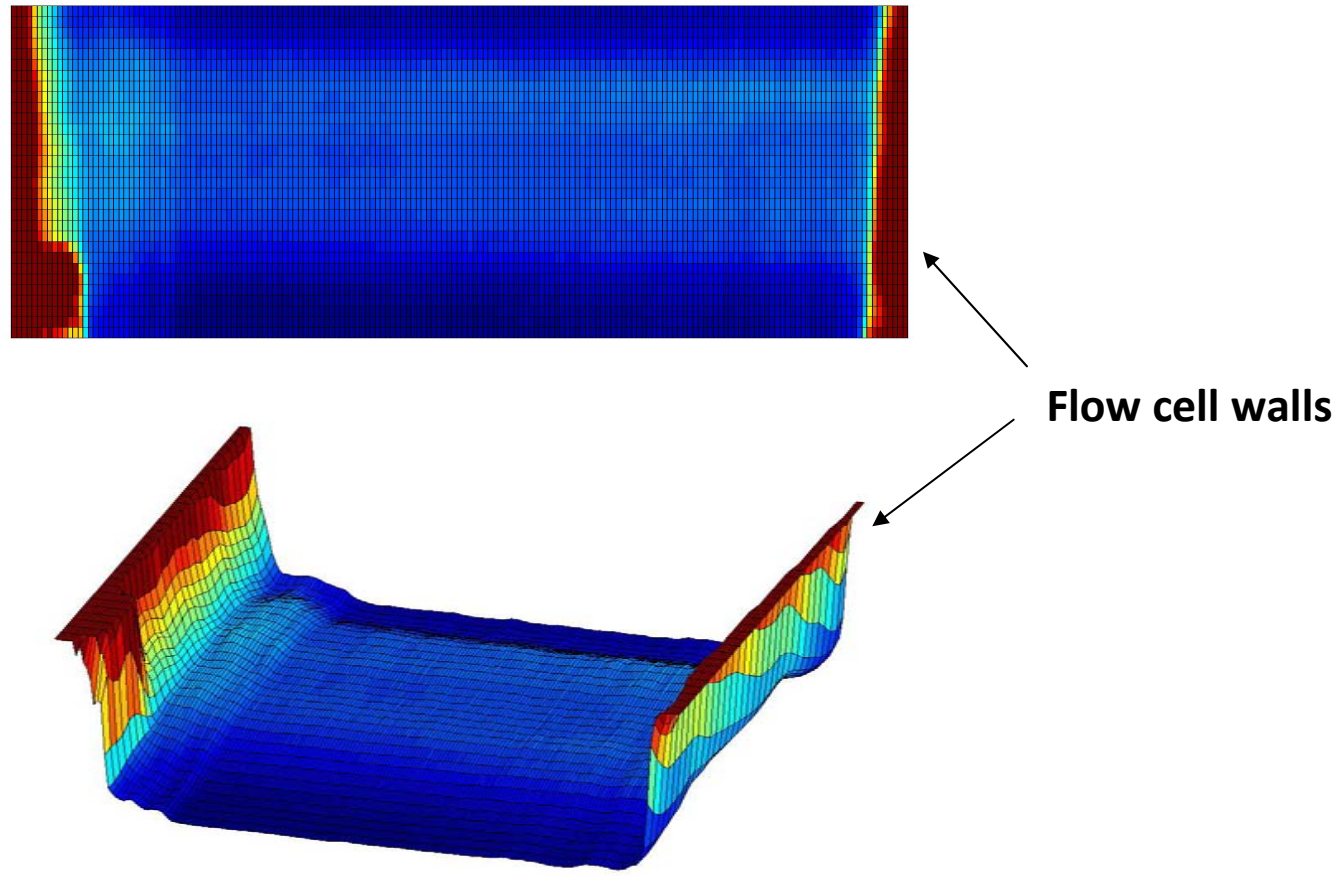
- Higher sensitivity
  - Noise spread out over millions of detector elements
  - High efficiency detector elements
    - More signal

- Noise discrimination
  - Particles have unique signal
    - Can discriminate against non-particle signals
      - Molecular scatter
      - High-energy photons
  - Scattering from walls or contamination does not affect other areas of sample volume

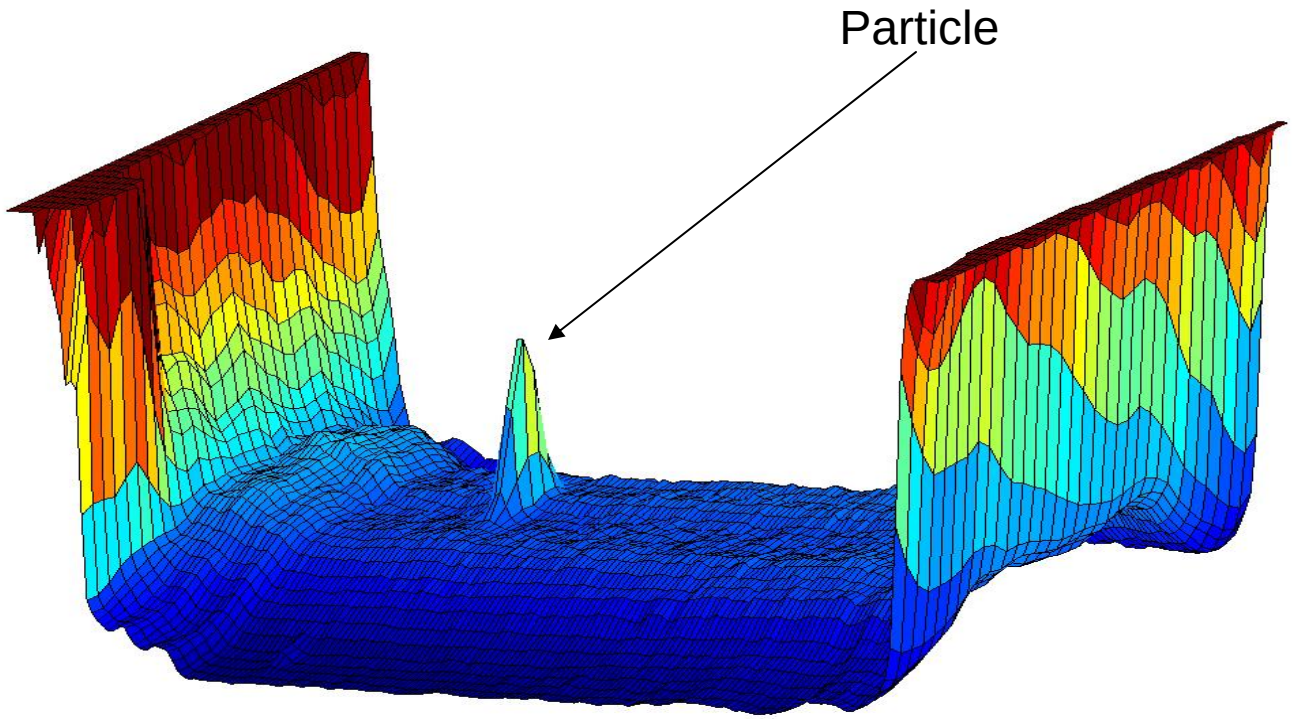
Additional Features and Benefits

- Ability to save images of detected particles while counting
  - Allows for off-line analysis
- Visualization of flow cell
  - Detect problems and/or changes
- Very good size resolution
  - ~5%

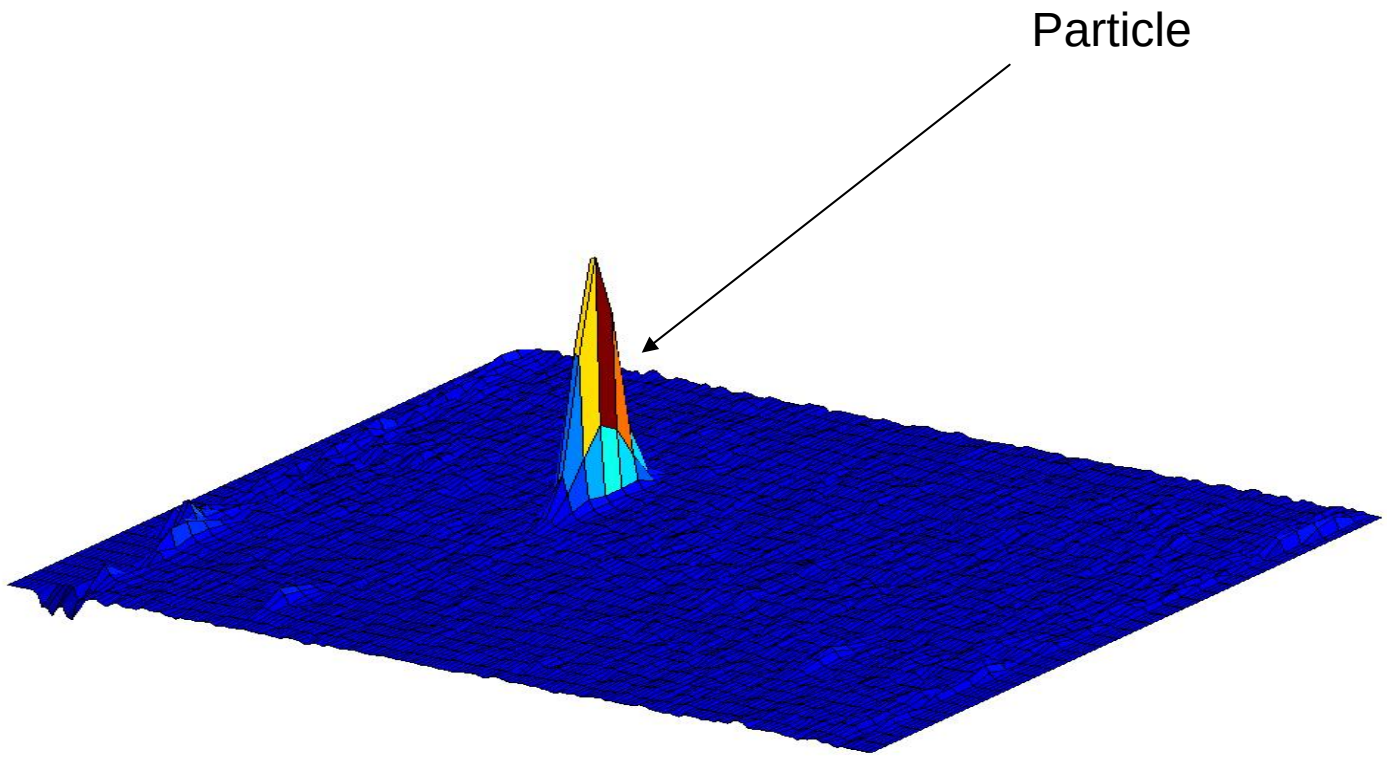
Background Imaging Grid



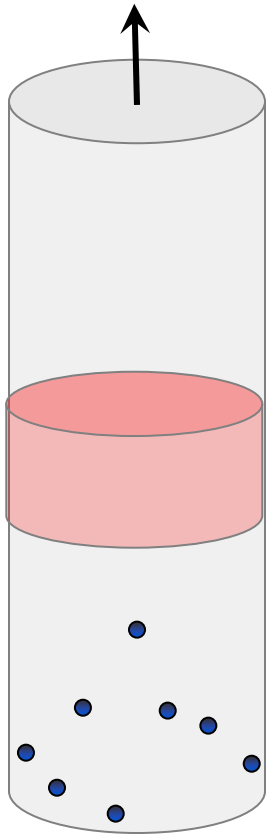
3-D Display of Particle on Background



Background subtracted

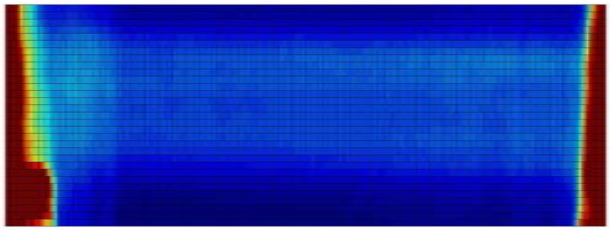


Particle Detection



Flow Cell

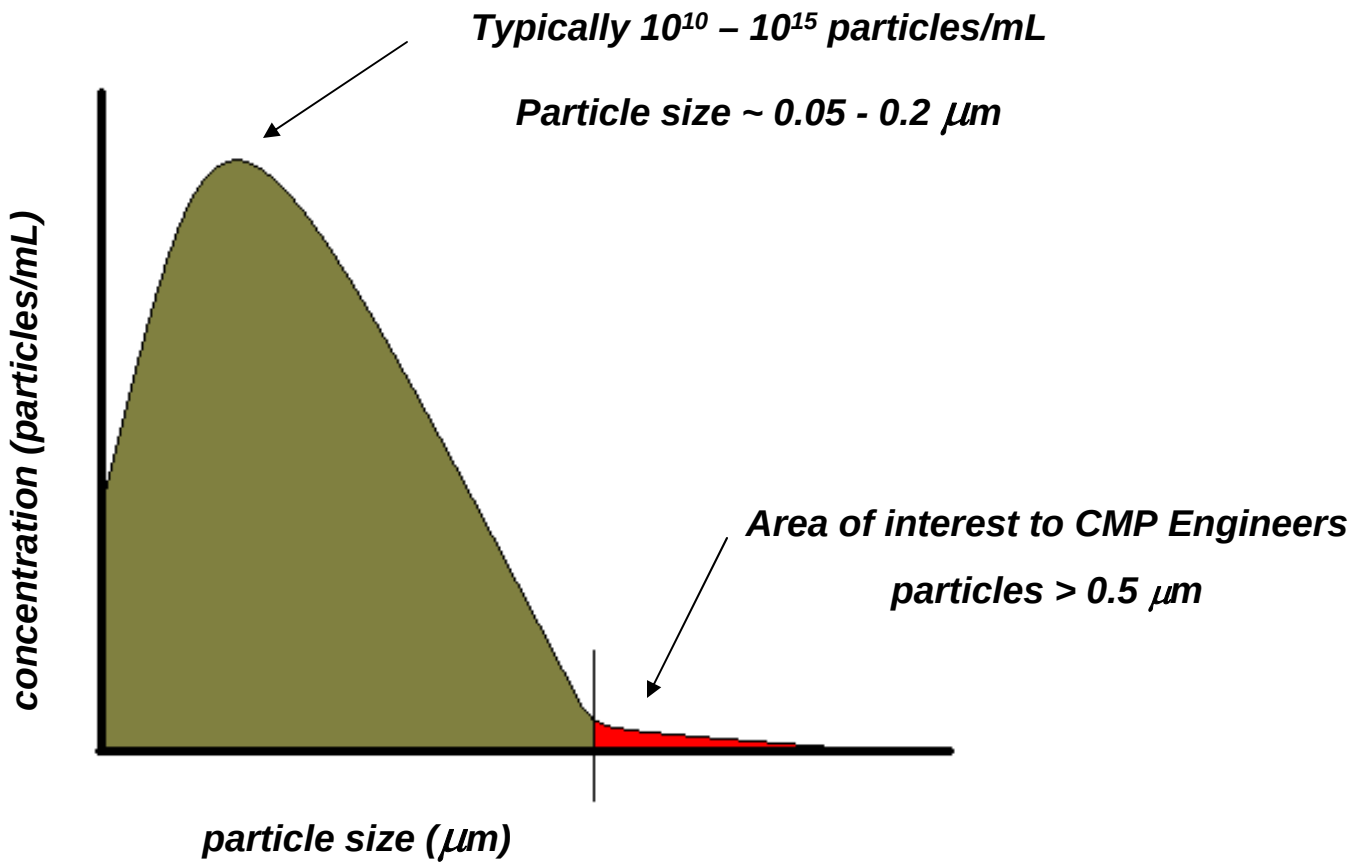
Imaging Zone



Improved Sensitivity

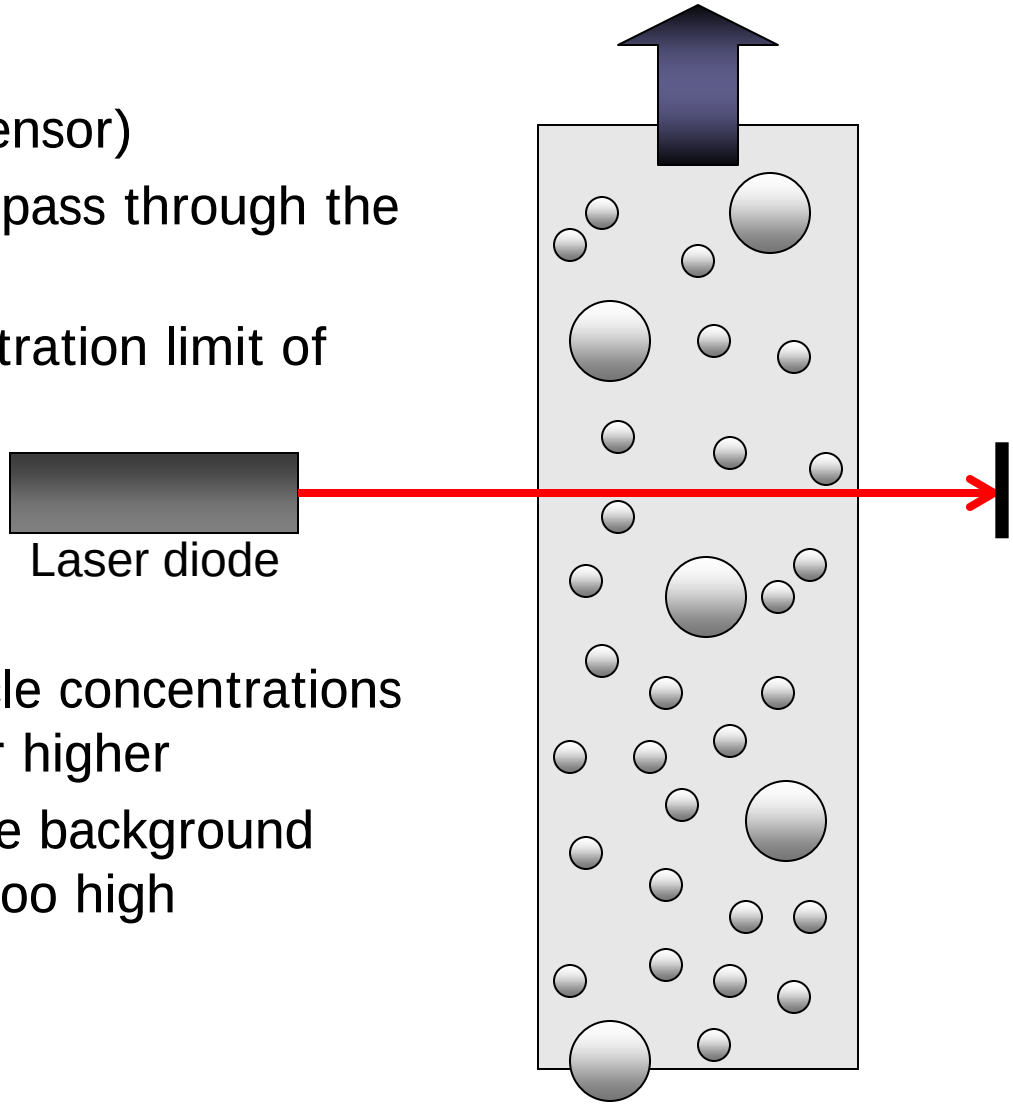
- 40 nm detection in liquid chemicals
- 30 nm detection in ultra-pure DI Water
- High sample volume
- Eliminate background noise and false counts
- Potential application for slurry measurements

Particle Distribution in CMP Slurry



Optical Particle Counter

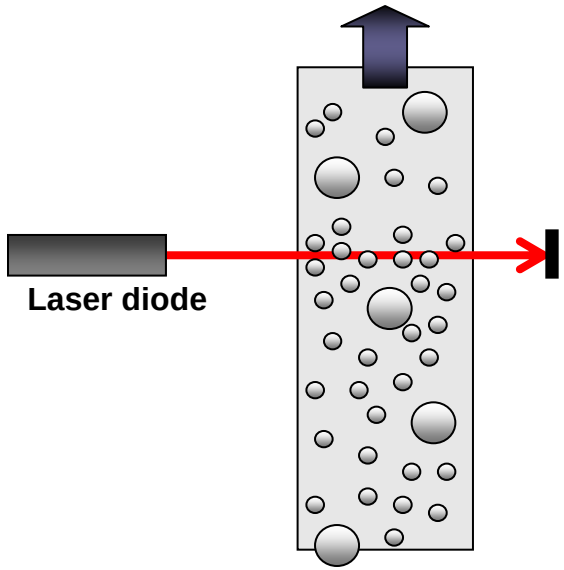
- SPOS (single particle optical sensor)
- Requires that a single particle pass through the laser path to operate properly
- 10^4 particles/mL is the concentration limit of most counters



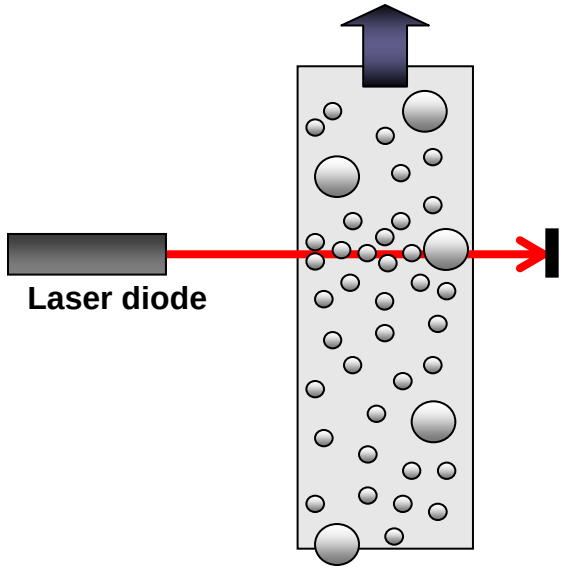
- In CMP slurries the small particle concentrations are usually 10^{10} particles/mL or higher
- Even with 10^3 dilution ratios the background particle concentration are still too high

What is the effect?

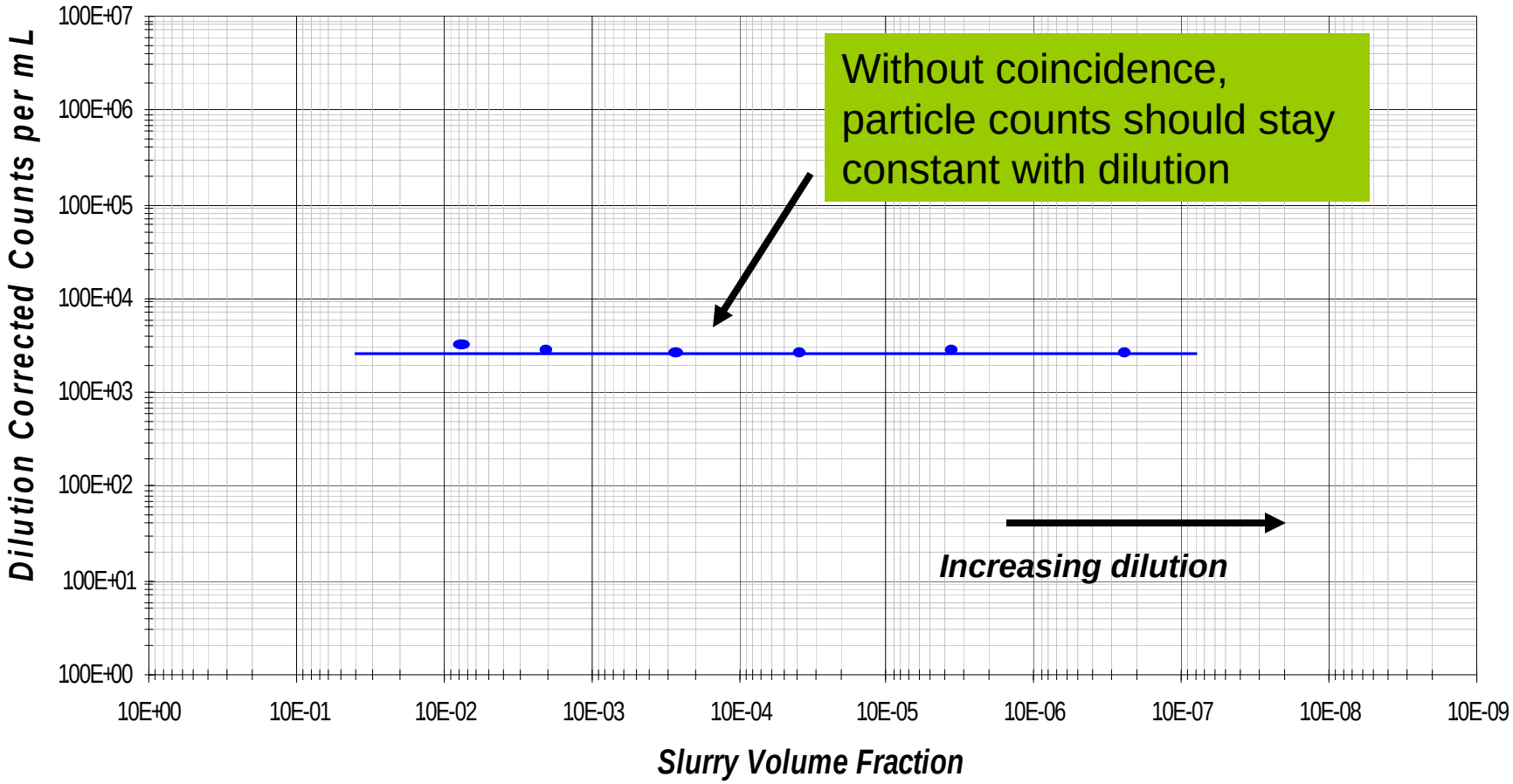
- Coincidence results
  - *Case 1*: Many small particles scatter the same amount of light as a large particles → resulting in mis-sized particles



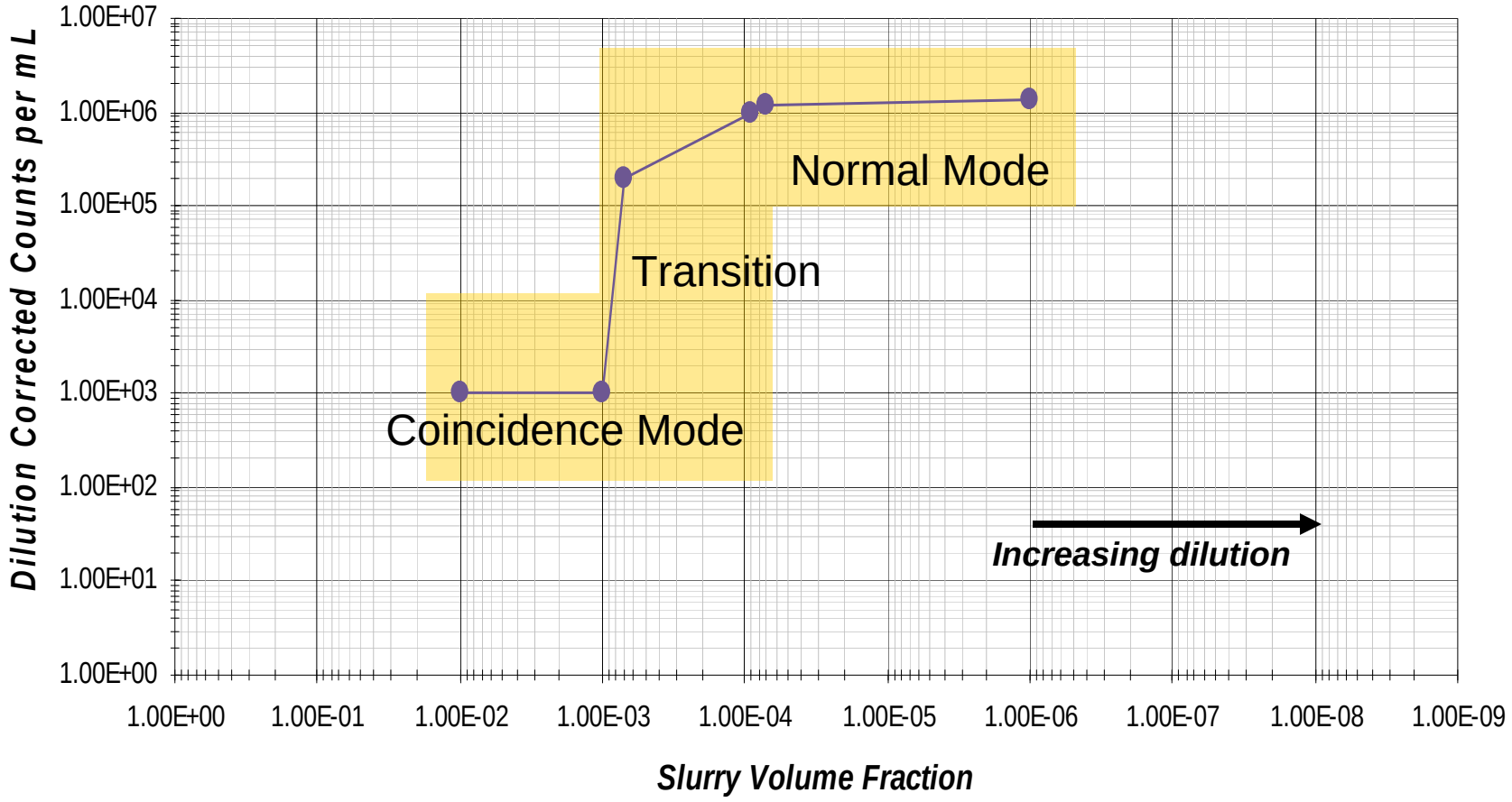
  - *Case 2*: Many small particles mask the larger particles → resulting in undercounted large particles



Dilution check for “coincidence”



Actual results with OPC



Dilution-Free Alternative?

- Approach #1
  - Use background elimination technique to substrate noise contribution from small slurry particles
- Approach #2
  - Take advantage of million^{+} element imaging grid to isolate the signals from small and large slurry particles

Summary

- ITRS guidelines are driving the need for improved metrology for water and liquid chemical monitoring
- Novel imaging technology designed to bridge the gap
  - Ability to measure 30 nm in water and 40 nm in chemicals
- Potential for addressing coincidence error in CMP slurry measurements