

Spatial Calibration of an Illumination Dome

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The influence of illumination geometry

Diffuse lighting flattens image and reduces contrast



Directional lighting enhances image depth and increases contrast, enabling surface relief to be observed.

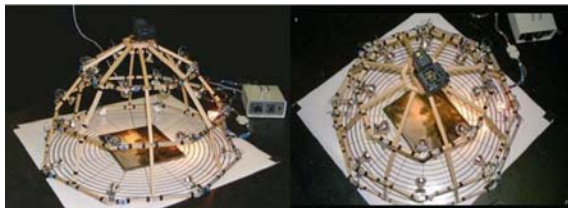
Conventional copystand

- Standard set-up for photographic copying
- Lamps at 45 degrees
- Camera normal to surface
- Minimises specular reflections from surface



Dome imaging

- Camera is fixed relative to object
- Illumination of object from many angles
- Capture a series of images in register

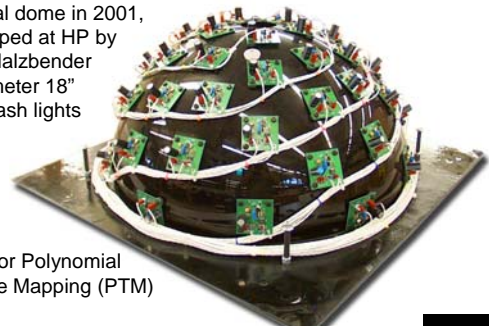


National Gallery, London (Courtesy of Joe Padfield)



Illumination dome

Original dome in 2001, developed at HP by Tom Malzbender
- Diameter 18"
- 40 flash lights



Used for Polynomial Texture Mapping (PTM)



PTM surface rendering

Create the impression of a surface being illuminated interactively by a light from any direction.

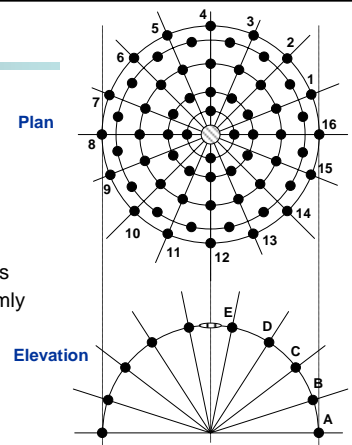


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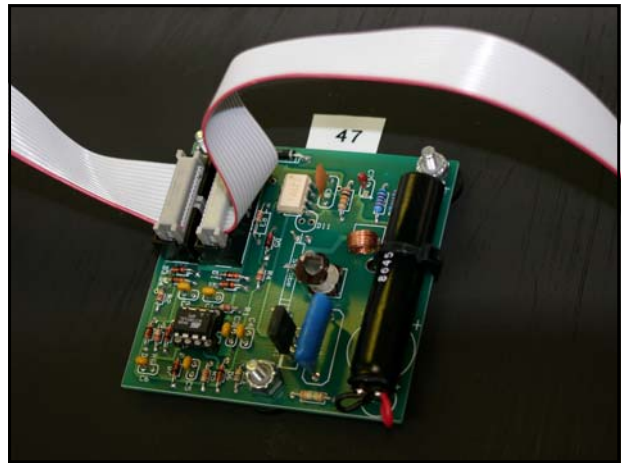
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Concept layout

- Planned in 2003
- 64 lights in total
- 5 horizontal tiers
- Aim to distribute lights approximately uniformly over the hemisphere

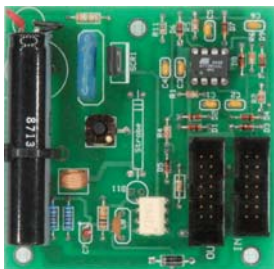


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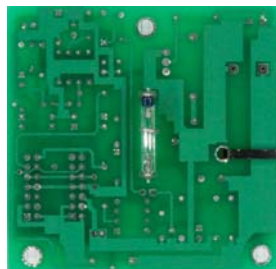


Flash board

Top view (outside)

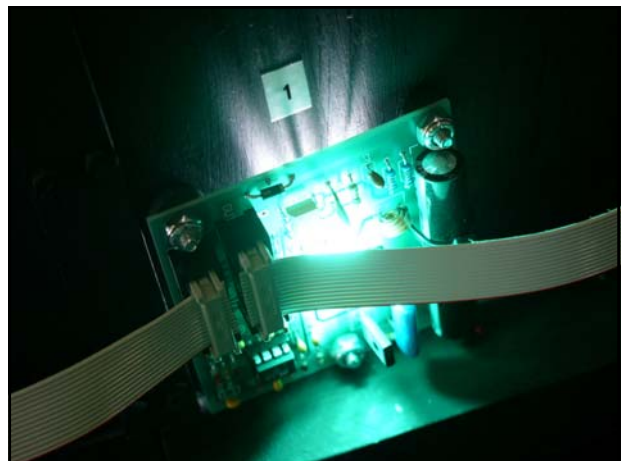


Bottom view (inside)



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Problem

Q. How to determine the coordinates of the lights on dome?

A. Principle of the sun-dial.

Calculate from observed coordinates of shadow tip.

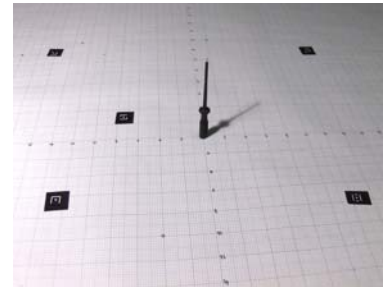


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Pin shadow formation

- Place steel pin vertically at centre of A1 sheet of mm graph paper.
- Capture series of pictures with the camera in normal mount, illuminated by each flash light.



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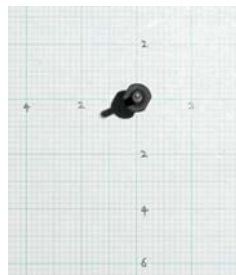
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Pin shadow images

Tier 4



Tier 5



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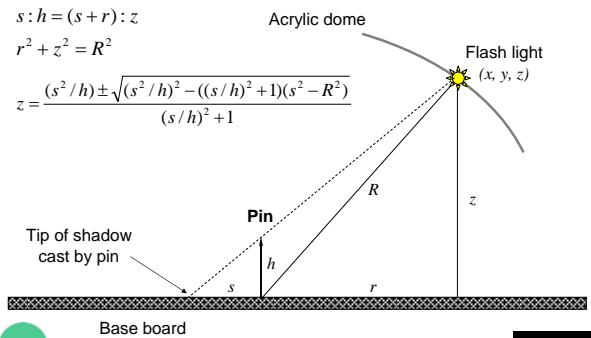
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Geometry of shadows

$$s : h = (s + r) : z$$

$$r^2 + z^2 = R^2$$

$$z = \frac{(s^2/h) \pm \sqrt{(s^2/h)^2 - ((s/h)^2 + 1)(s^2 - R^2)}}{(s/h)^2 + 1}$$



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Penumbra

- Light is not a point source
- Flash discharge is approx. 6mm in length



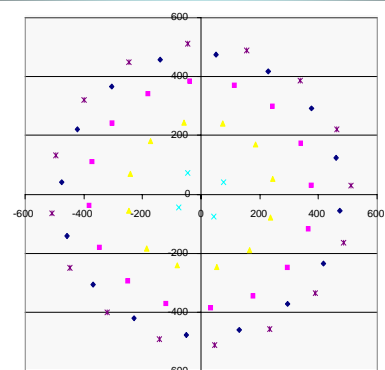
- Subtends angle of ~ 0.75 degree at pin tip
- Produces a penumbra or soft-edged shadow of pin



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Lamp coordinates – plan view

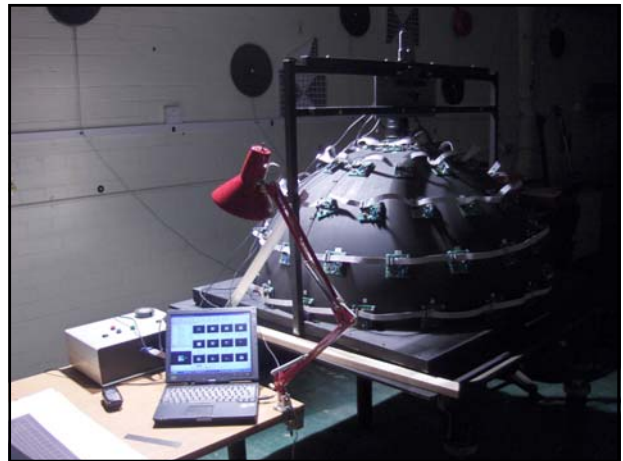
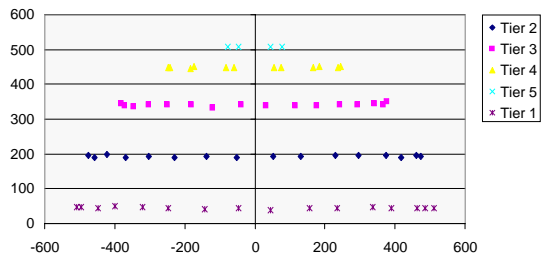


◆ Tier 2
 ■ Tier 3
 ▲ Tier 4
 × Tier 5
 × Tier 1

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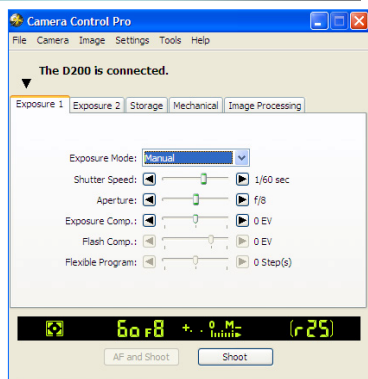
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Lamp coordinates - elevation



Computer control of camera

- Nikon D200 digital camera
- 17-55mm f2.8 zoom lens
- Connect to laptop PC via USB
- Camera control from graphic user interface.



Spatial Resolution

Finest detail in man-made objects is limited by:

- Finest tools
- Dexterity of the hand
- Acuity of the eye

Inherent resolution limit characteristic of medium.

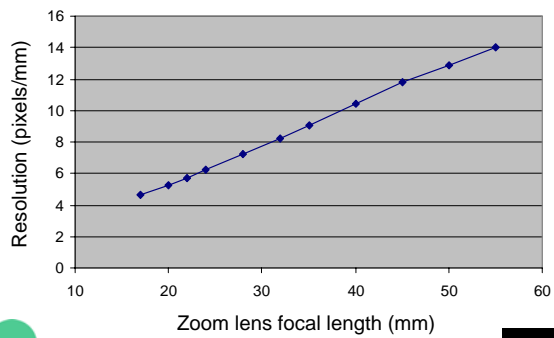
Limited to about 10 line-pairs/mm.



Stained glass window
Fairford Church, Gloucestershire



Zoom resolution



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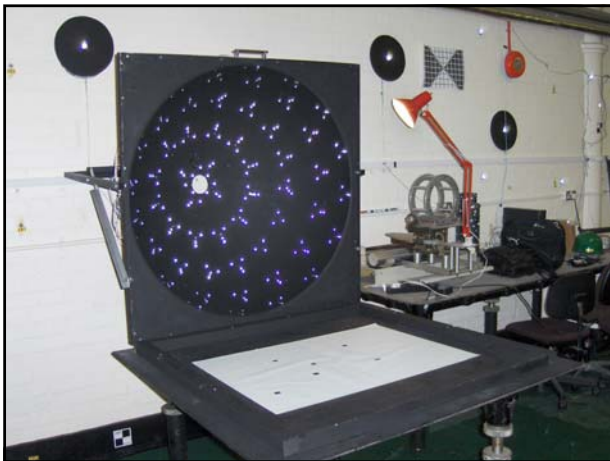
Alternative approach to geometry

- Use an advanced imaging technique
- Retro-reflective target on each lamp
- Capture multiple images of whole kit
- Record every point >3 times
- Apply photogrammetric technique of self-calibrating bundle adjustment to solve system and determine coordinates of every point.



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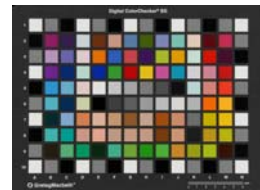
Next steps

Illumination profile



Image of white card

Colour characterisation



GretagMacbeth Color Checker SE

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Application to cultural heritage

Capturing objects from the museum collections at UCL:

- Petrie Museum of Egyptology
- Grant Museum of Zoology and Comparative Anatomy



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Conclusion

- Often it is not necessary to produce a true 3D image, just the illusion of an object or viewing environment.
- The PTM technique provides a convincing visualisation of moving a virtual light source over a virtual object.
- The method can be developed to extract 3D surface geometry, with a resolution comparable to laser scan.



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