Product Requirements Document: Automated Cosmetic Inspection Machine Optimax

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Customer: Optimax Inc/ Patrick Augino

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Revisions level	Date
E	12-08-2016

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Revision History

Revision	Description	Date
A	First revision: Defined the general idea of what our customer wanted our design to do. Mostly entailed the Vision section and the first few bullets of the Fitness for Use section.	10/29/16
B	Second Revision: Defined quantitative specifications such as range of test piece diameter. Added Environment, target users	11/13/16
C	Third Revision: Added “What we are not required to do” section	12/01/16
D	Fourth Revision: Included preliminary design and preliminary data. Added spring semester design schedule, team roles, revision history, and Appendix	12/14/16
F	Final Revision: Added finishing touches and number tweaks.	12/17/16

Vision:

Our customer wants a device that can find defects on a polished spherical surface and quantitate them automatically. The device must be able to output in the ISO 10110 standard, where the smallest defect size is 0.7 um. The device cannot be destructive towards the optic, and thus cannot touch the surface in any way. We are responsible for designing the device itself, and the code to process the images and output.

Team Roles:

Eric Kwasniewski-	Project Coordinator
Aaron Greenbaum-	Customer Liaison
Mark Ordway-	Scribe

Environment:

This device will likely be placed somewhere in the testing center at optimax.
It is prefered that the optic is not required to be in complete darkness as the testing center will have standard industrial lighting.

Temperature and Humidity

At room temperature and humidity (22 °C and 50% humidity)

- Will have access to outlet power
- Will be in shop floor environment, likely to be dust and vibrations

Support:

Optimax will provide a robotic arm to assist in any translational needs. The robotic arm can carry up to 3000 pounds. The robotic arm is able to move with precision of up to 2 micrometers.

Target Users

As of now, this device is to be used only by Optimax inspectors. They should be able to easily setup the optical piece and be able to leave the device running by itself.

Regulatory Issues:

Need to make sure that no patent infringement is made on the SAVVY Optics Inspector. Aside from that no other types of issues.

Design Schedule

Month	What we will have done
December	- Complete preliminary design draft - Acquire experimental data on effects of different illumination on surface imperfection - Obtain copy of Chapter 7 of ISO 10110 international standard
January	- Communicate with our adviser and customer to schedule weekly meetings - Begin programming the detection and analysis software - Come up with prototype designs in CAD
February	- Design details (pick out components for the prototype) - Begin prototype assembly - Finish up programming of detection software, continue working on analysis software
March	- Finish up the prototype - Finish up all programing of both detection and analysis software
April	- Have a working prototype (at least on an optical bench) - Tested data from this system - A planned method of how this system will be mounted

Fitness for Use:
The System must meet the required conditions and numerical specifications.

- Locate defects on a polished spherical Optical surface
- Quantize said defects according to the ISO 10110 standard
    - Find number and size of defects
- Do so automatically
- Do so non-destructively
- Measure coated and uncoated optics
- Be able to measure both reflective and transmissive optics.

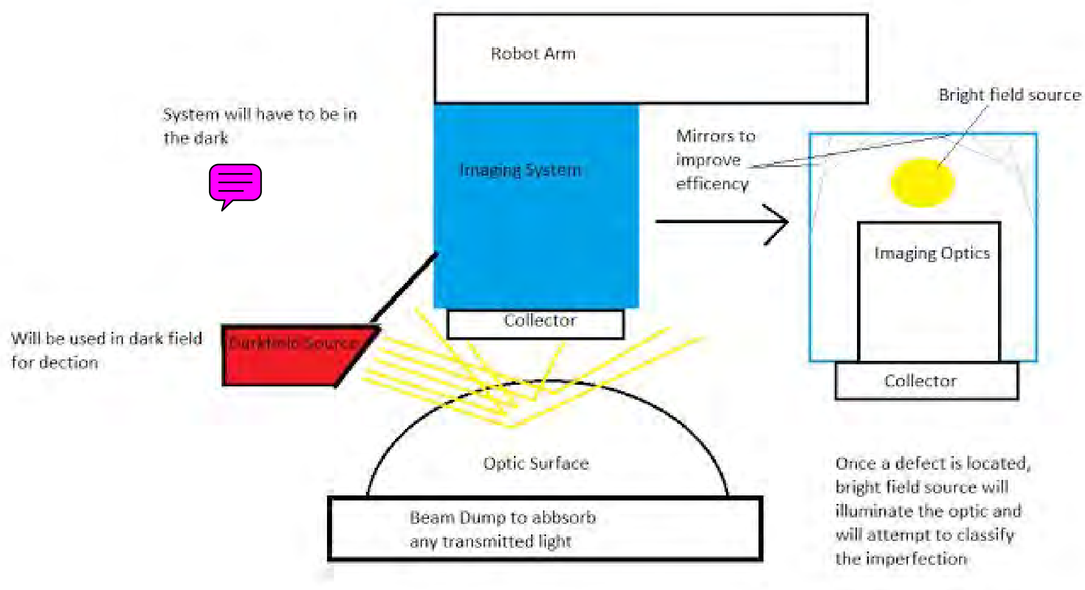
It is prefered that:

- The system is able to measure the defects in the Mil spec as well as the ISO 10110.
- The system be able to measure a wide range of radii of curvature (number not specified)
- The optical system itself be attached to the robotic arm while the optic be in place

Numerical Requirements		Comments
Smallest Measurable Imperfection	< 0.7 um	
Test Optic Diameter	10-300 mm	
Test Optic R number	> 0.75	The R number is the ratio between the radius of curvature and the diameter of the lens
Spectrum	400 - 700 nm	The optics will either reflect or transmit at this spectrum
Maximum measure time	1 hour	

What we are not required to do

- Design the translation mechanism
- Program the translation mechanism
- Have the system mount the optic
- Have the system find sub-surface damage
- Have the system be able to measure aspherical or freeform optics



- Darkfield illumination for increased contrast
    - Darkfield source: possibly a white light ring illuminator.
- Light from dark field source scatters when it hits a surface imperfection
- System scans optic and finds location of all defects
- System images defects and then sends image to computer to quantize defects according to ISO 10110 standard, a completely objective standard.
    - Uses a CCD detector

Preliminary Data

This data is used to understand the effects of different illumination settings on a surface imperfection in a similar environment to the Optimax environment.

Environment

At room temperature and humidity (22 °C and 50% humidity)
Industrial lighting overhead

Test piece

Uncoated optic, poor surface quality, 1 inch diameter, Convex spherical, unknown material, radius of curvature of 70 mm.

Microscope

Opti-tekscope, Model OT-HD

5-30 mm focal distance, 1-300x mag, 1 cm clear aperture.

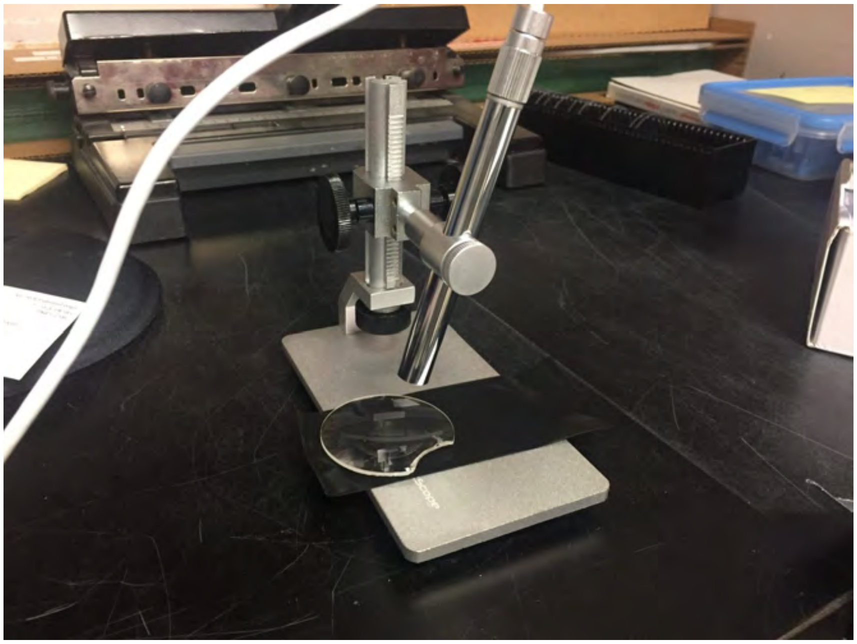


Figure 1: Opti-Tekscope imaging a lens surface. The industrial lighting is present and adding ambient light into the system. Black masking tape is used to absorb light from our improvised light source (Not in picture).

Light source

The first light source is a brightfield light source that has been integrated into the microscope. A ring of 8 LED lights surrounds the objective piece.

The second light source is a dark field light source meant to imitate the source shown in “design draft #1”. The light source is a cell phone light held at various angles similar to how it is depicted in “design draft #1”.

Data

Using this microscope, and test piece, the same spot on the lens was imaged under different lighting conditions at 20x magnification.

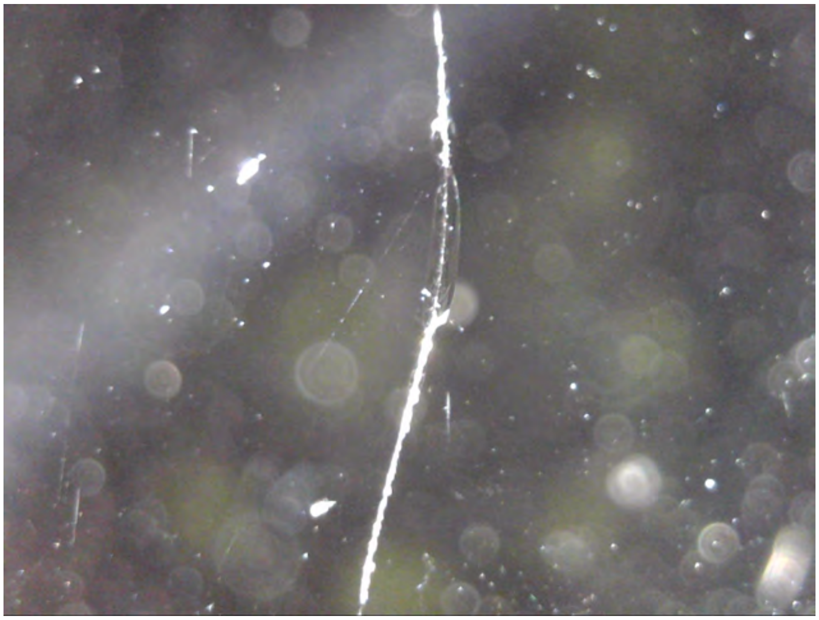
First with no source, using only the ambient lighting to image.

Then using the brightfield source that came with the microscope.

Lastly, using a phone to imitate a white light dark field source with the phone being held at different angles.

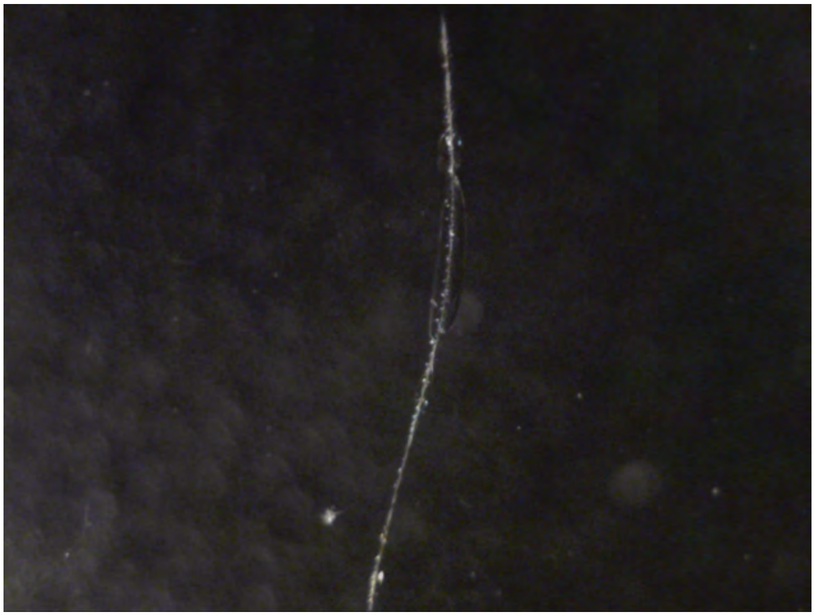
In each image there is a 500um wide scratch and a 1-7 um wide scratch-like imperfection to the left of the 500um wide one.

There are also many small surface imperfections (not dust) scattered across the lens surface.

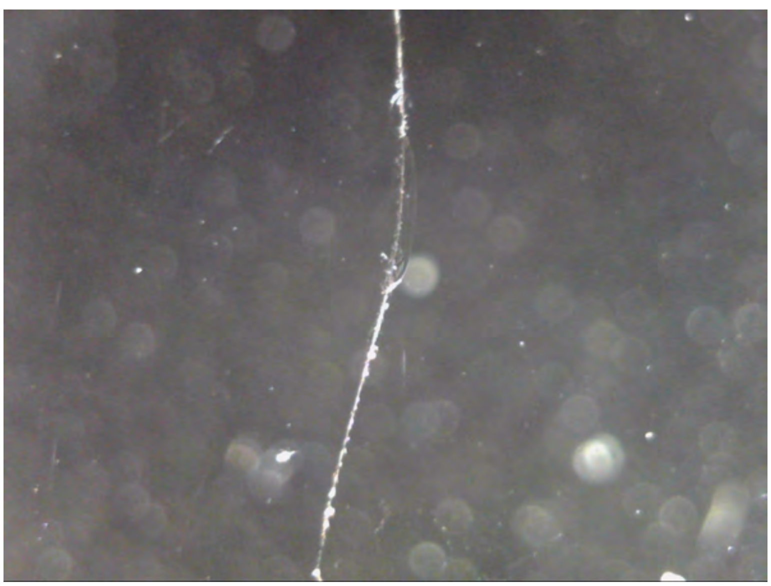


Picture 1: x20 mag picture of lens under Darkfield at 0 degrees. Ambient lighting still present.

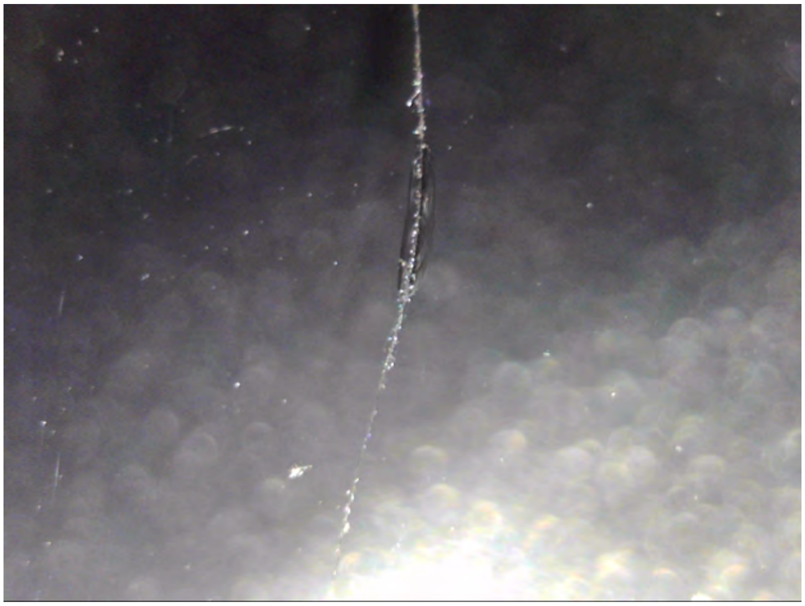
Picture 2: x20 mag picture of lens under integrated bright field.



Picture 3: Picture of lens with no additional lighting present. Only ambient light.



Picture 4: Picture of lens under darkfield lighting with source angled at 30 degrees above the ground. Less contrast of small features.



Picture 5: Picture of lens under darkfield lighting with source at 60 degrees from the ground. The light from the source can be seen at the bottom of the picture.

Picture 1 visibly shows the most surface imperfections out of all the other illumination methods. Picture 1 is a dark field source at 0 degrees from the ground. Using a darkfield source at a low angle may be the best approach to finding surface imperfections.

One interesting thing to note is the presence of ambient light in picture 1. This is the light from the industrial overhead lighting. Despite its noticeable presence in the image, the surface imperfections are still clearly visible. The background lighting may make it harder to write the program to detect/quantize the imperfections.

Appendix A
SavvyInspector™ SIF-4E

The SavvyInspectorTM model SIF-4E is the new, high resolution version of our popular SIF-4 software assisted scratch/dig evaluation of flat optical surfaces. Both instruments are designed specifically to reproduce the conditions of an in-reflection visual inspection described in Appendix C of MIL-PRF-13830B, “General specification governing the manufacture, assembly, and inspection of optical components for fire control instruments.” The factory calibrated inspection head of the SavvyInspector™ uses invariant illumination and detection optics and proprietary analysis software, allowing objective, repeatable, and recordable evaluation of scratch/dig surface quality.

The SIF-4E uses a 1.4 megapixel camera and higher resolution to perform more precise measurements and grading on very small features. It is recommended for micro-optics, and for components that are specified to 20- 10 or tighter.

Product Description: SavvyInspectorTM SIF-4E is a complete flat-optics inspection system consisting of:

1. A custom LED-based illumination assembly.
2. A detection assembly with a digital megapixel camera.
3. A manual z-stage for focusing to different part thicknesses.
4. A manual, encoded 100 mm x-y stage platform with rails for part holding and positioning.
5. Light baffles, base-stand assembly, and cabling.
6. A stand-alone computer with proprietary SavvyInspectior™ analysis software.

Scratch/Dig Standards Supported

MIL-PRF-13830B
MIL-C-675C
ANSI/OEOSC OP1.002:2009 Visibility Method
ISO 10110 general and coating imperfections (but not L-type imperfections)

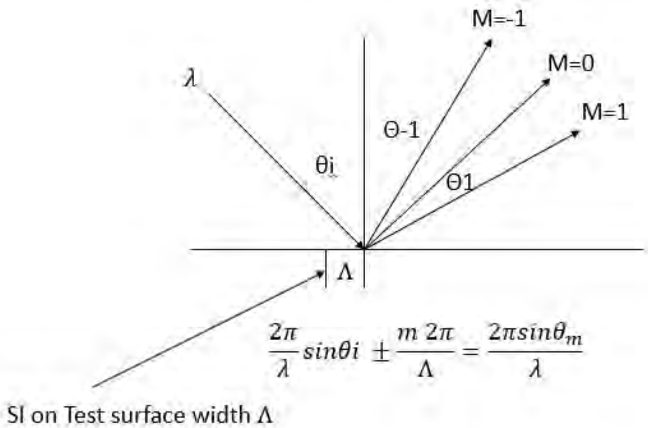
Version 5 Software

The SavvyInspectorTM operator interface in the new version 5 software is designed for easy factory-floor operation, while expanding its application in the role of “Master Inspector” for QA, QC and MRB decisions. The operator enters the inspection level required, and then uses the manual x-y stage to locate the desired defect on the real time viewing screen. The software reports the scratch grade or dig value automatically. Scratch lengths are measured with the click of the mouse. The "always on" inspection mode and programmable grade bars allow the operator to get real-time feedback on whether a selected imperfection is acceptable or not with a simple visual interface. There is no subjectivity; the grade is reported and the grade bar turns red if the imperfection is greater than the specification. When a careful review and documentation of a surface is required, the version 5 software provides data management tools to properly collect and file screen shots and inspection grades for each imperfection on a surface, including a summary log in CSV format for easy uploading into Excel or an inspection report. Accumulation rules can be applied using the SavvyAccumulator™ spreadsheet. Custom calibration files can be created for specific project or customer needs by the Quality Engineer as needed. The calibration data can then be saved and accessed from the inspection mode.

Feature	Specification	Comment
Inspection Head	1.4 Megapixel camera and fixed illumination and simulating reflection inspection for surface quality per MIL-PRF-13830B	Inspection setup is identical to that of MIL-PRF-13830B Annex C, MIL-C-675C and the visibility method described in ANSI/OEOSC OP1.002:2009
Camera Field of View	9 x 12 mm, digitally zoomable	Allows rapid location of imperfections
Inspection Area	One mm square in center FOV	Allows isolation of specific imperfection for evaluation
X-Y Stages	Manual encoded x, y slide stage with >100mm travel	Encoders read out distance moved since last mouse click allowing rapid evaluation of scratch length
Focus	Manual 70 mm Z-stage for focus. Depth of focus > 1 mm	Easily accommodates thick parts
Test surface reflectivity	System can measure coated or uncoated parts, filters, windows, splitters, cubes, and prisms.	Standard calibration files for metalized comparison standards are provided. Some custom calibrations or part fixturing may be required.
Test surface shape	Plano or mild concave surface	Designed for flat parts, but long radius concave parts can also be inspected
Reported Values	Scratch number- 10, 20, 40, 60, 80 Dig value – continuous from 5 to 70 ISO Grade – 0.025 to 0.63	Per MIL-PRF-13830B and ANSI/OEOSC OP1.002, visibility method ISO 10110-7 general and coating imperfections only
Comparison standards	Factory calibrated to FLIR/Brysen, Davidson comparison artifacts, as well as various plastic inspection paddles	Customer can generate and save calibration files for any artifact set
Instrument repeatability	> 95% repeatability of reported scratch or dig grade	Presumes > 20 measurements of a clean surface in a proper environment of a stationary part
Instrument reproducibility	> 90% reproducibility of reported scratch or dig value	Presumes the clean part is removed, replaced and repositioned to the same location > 20 times

Appendix B
Angular Spectrum

Visibility of surface imperfections (SI) is dependant on the viewing angle, wavelength of source, and width of the surface imperfection.



$$\frac{2\pi}{\lambda}sin\theta i \pm \frac{m\ 2\pi}{\Lambda} = \frac{2\pi sin\theta_m}{\lambda}$$

Diffraction pattern from single slit (SI) gives a since intensity distribution which contains zeros. If we look at the SI at the angle which the zero is, we will not see the SI.

Due to this, we will try to calculate the optimal wavelengths to use and use 2 wavelengths for imaging reduce the chance of this happening.