LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

LIGO-T070107-07-K *Advanced LIGO UK* January 2012

BOSEM
Test Specification

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This is an internal working note
of the Advanced LIGO Project, prepared by members of the UK team.

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http://www.physics.gla.ac.uk/igr/sus/

http://www.sr.bham.ac.uk/research/gravity/rh,d,2.html

http://www.eng-external.rl.ac.uk/advligo/papers_public/ALUK_Homepage.htm

1 Introduction and Scope

This document covers testing of the production BOSEM (D060218), used in the Advanced LIGO suspensions. Prior to testing, all BOSEM parts will have been cleaned and baked as detailed in the assembly document [1]. Testing will be carried out at two stages during the BOSEM assembly: on the part-assembled coil-former, and on the fully-assembled BOSEM. Further testing can then be carried out on the completed BOSEM assembly, using the Automated Test Equipment (T1100075), throughout the lifetime of the unit.

All testing steps described in the following sections take place within clean room facilities, with personnel dressed in clean room garb, undertaking UHV component handing requirements and any necessary ESD precautions. Note that, testing should be conducted in an environment where temperatures are consistent with the LIGO sites and facilities (i.e. ~ 20°C ±2°C).

1.1 Version History

Revision 6	Updated to include ATE deliverables, logs of ATE unit part lists and serial numbers. Revised figures 5, 6 and 7. Added sections on setting up and procedure for using ATE equipment. Attached text file archive containing all production BOSEM ATE data logs. 28th February 2011 (SMA).
Revision 7	Updated to include re-scoped and renamed OSEM ATE (i.e. providing testing of NPOSEMs, BOSEMs and AOSEMs). 27th January 2012 (SMA).

1.2 Acronym List

ATE	Automated Test Equipment
AOSEM	Advanced LIGO Optical Sensor and Electro-Magnetic actuator
BOSEM	Birmingham Optical Sensor and Electro-Magnetic actuator
DMM	Digital Multi-meter
DVM	Digital Volt-meter
ESD	Electro-static Discharge
IRLED	Infrared Light Emitting Diode
LCR	Inductance Capacitance and Resistance meter
NPOSEM	Noise Prototype Optical Sensor and Electro-Magnetic actuator
PD	Photodiode
SUS	Suspensions Working Group
UHV	Ultra High Vacuum
UOB	University of Birmingham

1.3 References

[1] T060233-03-K, *S. M. Aston and D. Lodhia* - "BOSEM Assembly Specification".

2 Test Procedure

During BOSEM assembly [1], testing is carried out at two stages:-

- Tests are performed on the part-assembled coilformer (see Figure 1), measuring the coil insulation using a DVM. This test will provide an early indication of any faults with the flex-circuit and coil winding.
- Testing of the coil insulation as well as measuring the IRLED and PD currents, coil inductance and coil resistance of the fully-assembled BOSEM (see Figure 2) are conducted. These utilize a high voltage power supply and the ATE.

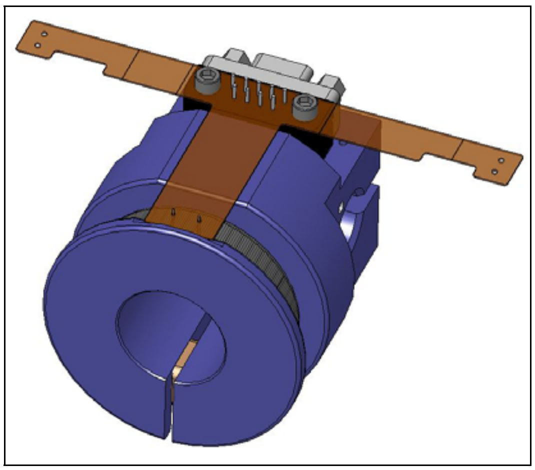

***Figure 1** - Coil-former assembly.*

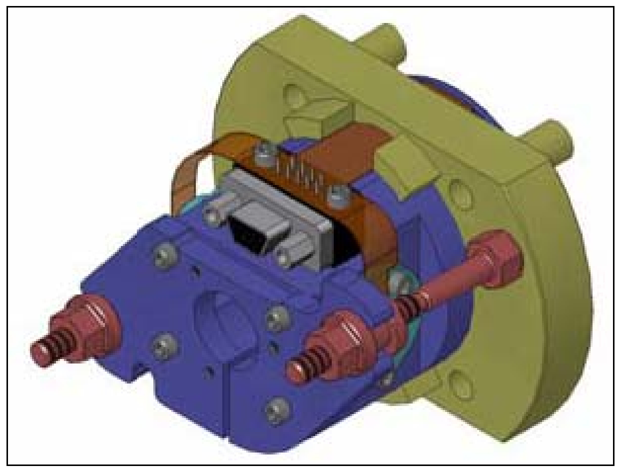

***Figure 2** - Complete BOSEM assembly.*

2.1 Part-assembled BOSEM Testing

The results of these initial measurements are not required to be recorded. However, these tests must be passed before proceeding with the remaining assembly tasks. Any failures need to be diagnosed and rectified, for example by determining if the fault is caused by the coil winding or the flexi-circuit. The equipment used throughout the duration of these tests can be found listed in Appendix B.

2.1.1 Coil Continuity

The first test will measure the coil continuity (see Figure 3). To use the DVM, switch on and select the resistance function. Set the resistance range to 0-200 Ω; most DVMs have the option of this range. Alternatively, choose an appropriate range on the DVM, ensuring that it will measure approximately 38 Ω. Connect one of the DVM's probes to the start of the coil winding. Connect the second probe from the DVM to the end of the coil winding. Ensure that probes are in contact with the copper core and not the insulation around the wire, the flexi-circuit or clean room gloves. Check that the resistance is within the required range (see Appendix A).

2.1.2 Coil Insulation

This second test will check the resistance between the start (and end) of the coil winding and the aluminum coilformer. Set the DVM resistance to the highest available range and place the probes at the start of the coil winding and the body of the coil-former. Check that there is no continuity between the start of the coil winding and the coilformer. Repeat this test again, but this time using the end of the coil winding, instead of the start.

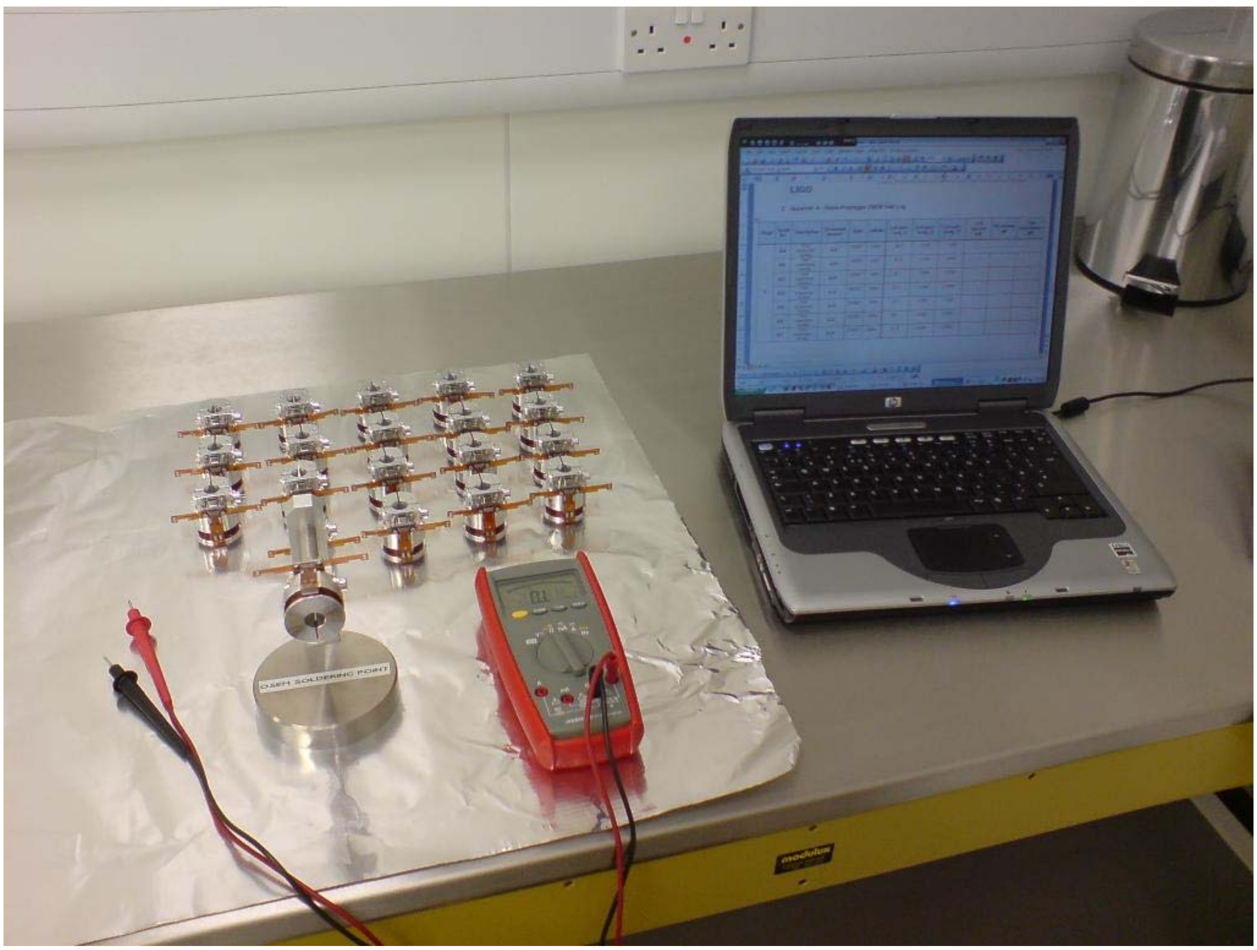

Figure 3 *- Testing carried out on part-assembled coil-former using the DVM.*

2.2 Fully-assembled BOSEM Testing

This stage consists of two parts, which are carried out on the complete fully-assembled BOSEM:-

- High-voltage breakdown testing.
- Measurement of BOSEM parameters using the ATE.

The equipment used throughout the duration of these tests can be found listed in Appendix B and C.

2.2.1 Insulation Breakdown

The purpose of this test is to ensure there is no breakdown of the coil winding insulation, thus eliminating the risk of producing a short circuit with the coilformer. A high-voltage power supply is used to apply 200 V at 20 mA (max). This test also ensures the insulation integrity of the connector and flexi-circuit. However, it should be noted that the connector's breakdown potential is rated at 300 V maximum.

2.2.1.1 Setup

The positive terminal of the power supply is connected to the coil via a male 9W μ-D connector, and the negative terminal is connected to the coilformer via a crocodile clip attached to one of the adjuster shafts (D060109) of the BOSEM. Connected between the power supply and BOSEM is an indicator box, consisting of a 10 KΩ resistor and LED. A remote activation switch is connected to the rear of the high voltage power supply, as shown in Figure 4.

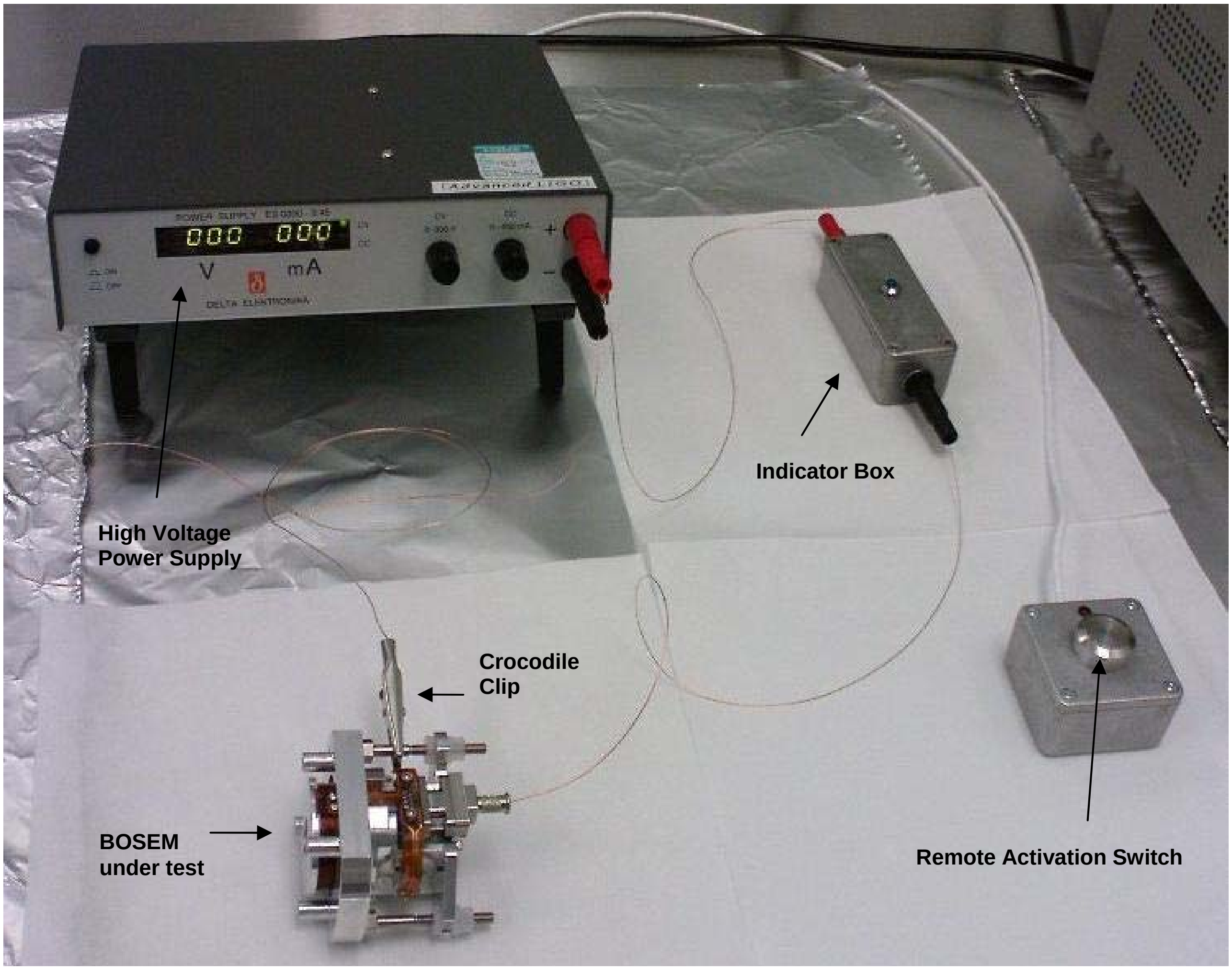

Figure 4 *- Setup of the insulation breakdown testing. A high voltage power supply, indicator box and BOSEM complete the circuit. The remote activation switch enables a current flow.*

2.2.1.2 Test procedure

Ensure that the BOSEM is placed on an insulating mat or clean wipe. Switch on the power supply and set the voltage and current at 200 V and 20 mA limit, respectively. Note that the power supply will only supply the high voltage when the remote push switch is activated. The nominal state is therefore for the switch to remain open and the high voltage disabled. Connect the 9W μ-D connector to the BOSEM and clip the crocodile clip to one of the adjuster shafts. The red light on the activation switch box will be flashing. Press down the button on the activation switch box and hold it down. The red light will stop flashing and will remain on continuously. The power supply will be activated and the high-voltage applied to the coil winding. Check that the blue LED in the indicator box does not light up (if the blue LED in the indicator box is illuminated, then this indicates a fault with the coil winding and hence the BOSEM has failed the test). Release the activation switch after approximately 5 seconds; this will remove the high-voltage from the

BOSEM under test. Carefully remove the crocodile clip and disconnect the 9W μ-D connector. Repeat this procedure for all BOSEMs.

2.2.2 OSEM ATE

This test consists of connecting a fully assembled NPOSEM, BOSEM, or AOSEM, to the ATE. Then over a period of approximately 30 seconds, measurements of the key parameters are taken and stored in a log file. It is expected that these measurements will be repeated, as required, over the lifetime of the unit. Hence this monitoring allows for definitive diagnoses of any faults that may develop as a consequence of mishandling, cleaning and baking, shipping or misuse etc.

2.2.2.1 Setup

The complete OSEM ATE setup can be seen in operation in Figure 5. The Keithley and Wayne-Kerr instruments should first be connected together with the GPIB cable, ensuring the jack-posts are fully tightened to secure the connectors in place. The ICS Electronics USB-to-GPIB Controller can then be attached to the GPIB cable (either at the rear of the Keithley or Wayne-Kerr), again ensure the jack-posts are fully tightened. Then the following connections need to also be made:-

- Connect 3 × 4 mm flying leads (red, black and white) between the front-panel of the Keithley DMM and the DMM inputs on the front-panel of the UoB Interface Box.
- Connect 4 × BNC leads (black, red, orange/blue and yellow) between the front-panel of the Wayne-Kerr LCR meter and the UoB Junction Box, whilst maintaining their order in the sequence.
- Connect 2 × 4 mm flying leads (red and black) between the front-panel of the UoB Junction Box and the LCR inputs on the front-panel of the UoB Interface Box.
- Connect 1 × 4 mm flying lead (green) between the front-panel of the UoB Junction Box and the rear-panel of the UoB Interface Box.
- Connect the Low Voltage Power Supply to the rear-panel of the UoB Interface Box. Note that, tip center is positive at 9 Vdc. Power-up the unit.
- Connect both Keithley and Wayne-Kerr units to the mains. Ensuring they are configured for operating at the correct mains voltage. Power-up both units.
- Connect 1 × USB type A-B lead between any Laptop USB port and the rear-panel of ICS Electronics GPIB-to-USB Controller.
- Connect 1 × USB type A-B lead between any Laptop USB port and the rear-panel of UoB Interface Box.
- Connect the OSEM interface lead (9W sub-D to 9W μ-D) to the front-panel of the UoB Interface Box. Note that, this item needs to be cleaned and air-baked (Class-B) for contact with Class-A OSEMs.

Power-up the laptop and wait while loading the operating system. During the booting process the "OSEM-ATE" user is prompted to supply a password, "ate" + the 3 digits of the unit's serial number provide the default user password.

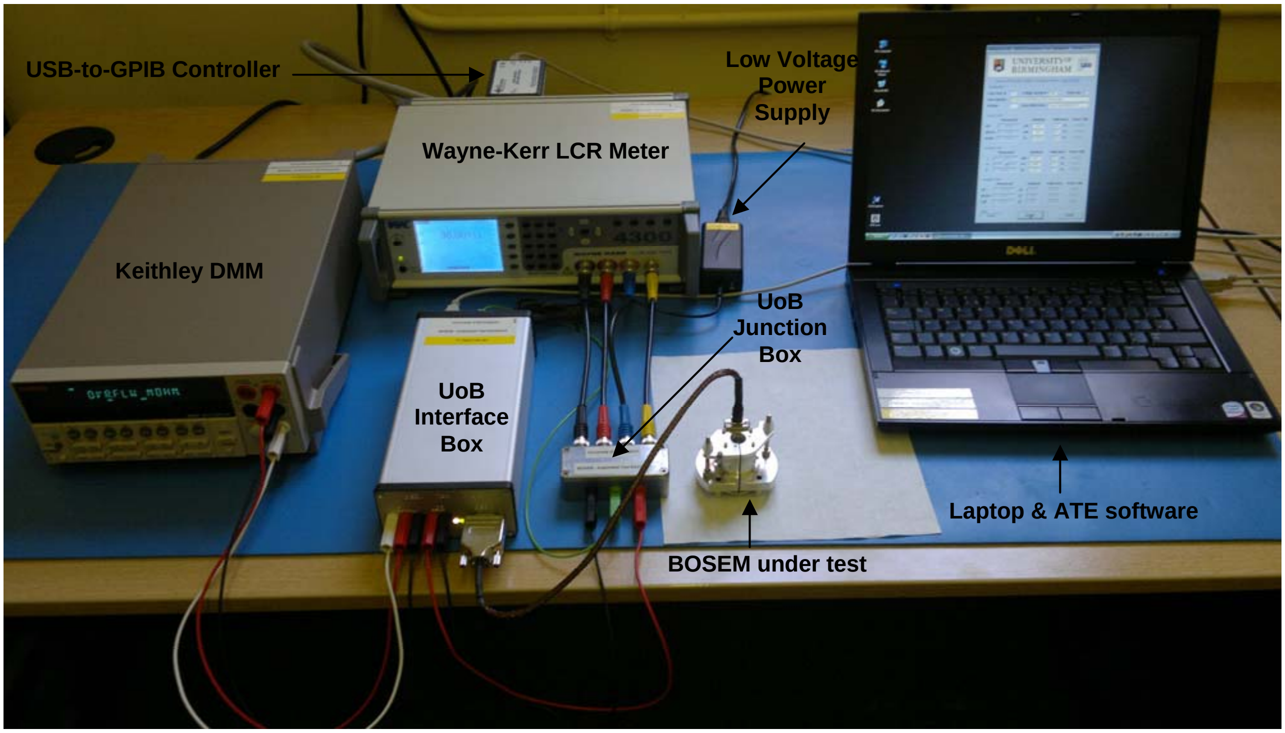

Figure 5 *- Operational setup of the OSEM ATE. The BOSEM under test has it's parameters measured and sent to the laptop via the GPIB/USB interface.*

2.2.2.2 Test Procedure

Place the OSEM to be tested face-down on a grounded ESD mat (the pins of 9W μ–D connector should be visible at the rear of the unit), then connect the unit to the UoB Interface Box via the connector.

If not already running, execute the test application "ATE.exe" (short-cut available on the windows desktop). Once running the ATE application, an interface similar to that shown in Figure 6 will be presented to the user. Ensure the "Serial #" text field is consistent with the three-digit serial number of the OSEM under test. If the "Auto Inc." box is checked, each new test will automatically generate and fill out the three-digit serial number text field using an incremental count. The "Description" field specifies the configuration of the OSEMs and the location where the tests are being conducted. The initials should be filled out by the engineer/operator carrying out the test. Check that the "Directory" contains the correct path in which the data is to be stored. Finally, ensure that the correct nominal values and tolerances are being applied by checking the correct OSEM type is selected (i.e. NPOSEM, BOSEM or AOSEM).

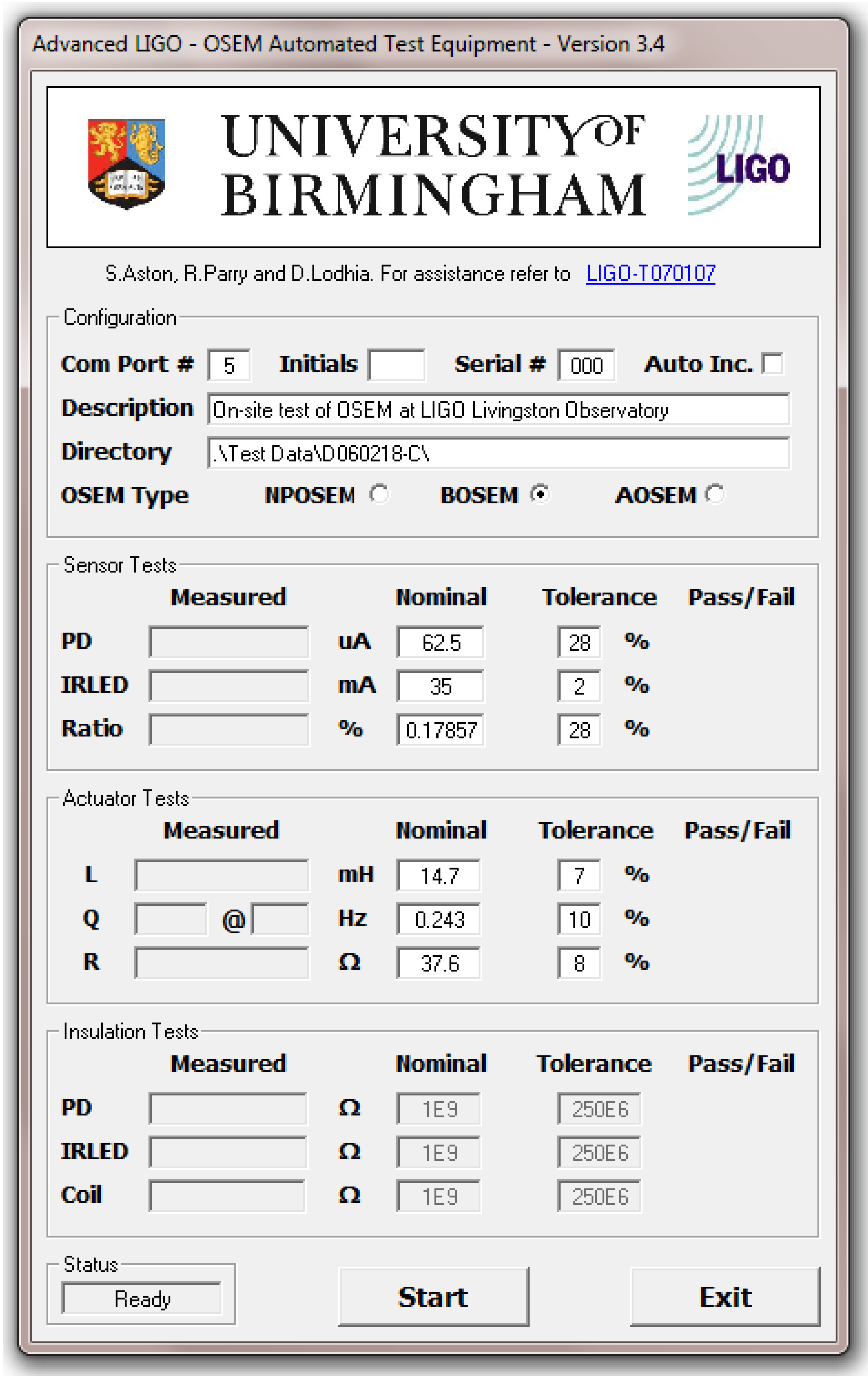

Figure 6 *- User interface of OSEM ATE software.*

On activating the "Start" button, the ATE will commence testing OSEM parameters. Upon completion, results will be displayed in the measurement fields. A comparison is made against the nominal values using the stated tolerance levels, and a “Pass” or “Fail” status message will be displayed. The data generated shall be automatically saved into individual ASCII text files for each unit, as shown in Figure 7. Subsequent tests of the same unit are then appended to this existing data file, thus providing the history of each unit. Data files can be analyzed with MATLAB scripts for example, or inspected manually.

```
Advanced LIGO - BOSEM Automated Test Equipment - Version 3.1
C:\ATE\Test Data\D060218-C\SERIAL_No012.txt             2011/01/19    14:44:03
AWP           BOSEM tests at UoB following retro-fit of Vishay IRLED

Parameter     Measured      Nominal       Tolerance     Pass/Fail


Sensor
PD(uA)        69.49         62.5          28%           PASS
IRLED(mA)     35.00         35            5%            PASS
Ratio(%)      0.20          0.17857       28%           PASS

Actuator
L(mH)         14.85         14.7          5%            PASS
Q@100(Hz)     0.244         0.243         5%            PASS
R(Ohms)       37.67         37.6          5%            PASS
```

***Figure 7** - An example of the typical contents of an OSEM ATE data file.*

Once the units are shipped to their appropriate destination, it is anticipated that further testing will be conducted on the BOSEMs at various stages of their lifetime. These measurements can be carried out at any of the LIGO sites in accordance with the test procedure outlined within this section.

3 Appendix A: Acceptable Test Parameters

The following table lists the acceptable pass criteria for the physical quantities measured throughout the tests:-

Quantity	Nominal Value	Pass Criteria	Notes
Coil start – end, Ω	37.6	Within ± 5%	-
Coil start – body, Ω	>250 M	>250 M	There should be no continuity between the coil start and the body
Coil end – body, Ω	>250 M	>250 M	There should be no continuity between the coil end and the body
LED current, mA	35	Within ± 2%	Fixed by IRLED drive current
PD current, µA	45 - 80	Within ± 28%	Nominal value between each batch may vary
Coil inductance, mH	14.7	Within ± 7%	-

Table 1 *- Tolerances for measurement parameters.*

4 Appendix B: Manual Test Equipment Part Lists and Serial Numbers

The following equipment has been used throughout the duration of the tests:-

Device Type	Manufacturer	Model	Serial Number
DVM	Iso-Tech	IDM 97 II	35002608
High voltage power supply	Delta Elektronika	0300 – 0.45	727402000057

Table 2 *- Specifications of the manual test equipment.*

5 Appendix C: ATE Part Lists and Serial Numbers

Device Type	Manufacturer	Model	Serial Number
LCR meter	Wayne-Kerr	4300	1046389
DMM	Keithley	2000	1304743
USB-to-GPIB Controller	ICS Electronics	488-USB	1010036
Laptop	Dell	Latitude E6400	196-431-585-31
Low Voltage Power Supply	mascot	2121	-
ATE Interface Box	UoB	T1100075	001

Table 3 - *OSEM ATE* s/n 001 (shipped to CIT)

Device Type	Manufacturer	Model	Serial Number
LCR meter	Wayne-Kerr	4300	1046381
DMM	Keithley	2000	1305146
USB-to-GPIB Controller	ICS Electronics	488-USB	1010037
Laptop	Dell	Latitude E6400	152-895-938-59
Low Voltage Power Supply	mascot	2121	-
ATE Interface Box	UoB	T1100075	002

Table 4 - *OSEM ATE* s/n 002 (shipped to MIT)

Device Type	Manufacturer	Model	Serial Number
LCR meter	Wayne-Kerr	4300	1046388
DMM	Keithley	2000	1305154
USB-to-GPIB Controller	ICS Electronics	488-USB	1010185
Laptop	Dell	Latitude E6400	131-128-115-23
Low Voltage Power Supply	mascot	2121	-
ATE Interface Box	UoB	T1100075	003

Table 5 - *OSEM ATE* s/n 003 (shipped to LLO)

Device Type	Manufacturer	Model	Serial Number
LCR meter	Wayne-Kerr	4300	1046386
DMM	Keithley	2000	1189131
USB-to-GPIB Controller	ICS Electronics	488-USB	1010035
Laptop	Dell	Latitude E6400	239-967-232-03
Low Voltage Power Supply	mascot	2121	-
ATE Interface Box	UoB	T1100075	004

Table 6 - *OSEM ATE* s/n 004 (shipped to LHO)

Device Type	Manufacturer	Model	Serial Number
LCR meter	Wayne-Kerr	4300	0846159
DMM	Keithley	2000	1210207
USB-to-GPIB Controller	ICS Electronics	488-USB	806193
Laptop/PC	*Any*	*Any*	-
Low Voltage Power Supply	mascot	2121	-
ATE Interface Box	UoB	T1100075	005

Table 7 - *OSEM ATE* s/n 005 (retained at UoB)