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| --- | --- | --- | --- |
| Experiment Name | Quantum diamond magnetometry | Date | 3/23/2024 |
| Associated LUA(s) | Nicholas Swanson-Hysell, Yiming Zhang, Anthony Fuentes | Version |  |
| Location | McCone 349 | | |
|  |  |  |  |
| Approved by PI | | Date |  |
|  |  |  |  |
| Approved by LSO | Date |  |

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# Integrated Safety Management

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| --- | --- |
| **Take ownership of your safety!**  Before starting any work, ask yourself:   1. What will I be doing? 2. Do I know what the hazards are? 3. Do I have everything I need to do the job safely? 4. Am I doing the job safely? 5. What can we do better? |  |

# Section 1 - Purpose

This Standard Operating Procedure (SOP) outlines requirements to be considered by an authorized user of the quantum diamond microscope (QDM) as well as describes the normal operation of the laser and any hazards that may be encountered during normal operation. The SOP explains how to minimize any hazards and how to respond in an emergency situation.

This document is to be reviewed one year from the date of approval or as conditions warrant, whichever is the shorter time period.

# 

# Section 2 - Personnel

Authorized Personnel

The quantum diamond microscope (QDM) may be operated only by authorized personnel who are fully cognizant of all safety issues involved in the operation of such a device. These personnel are to ensure that the laser is only operated in the manner laid out in this document. To become an authorized user, one must:

1. Complete [**EHS 301 – Laser Safety Training Initial**](https://jwas.ehs.berkeley.edu/lmsi?searchText=EHS%20301) e-Course
2. Read and fully understand the SOP
3. Receive hands-on training on the Type of Laser(s) or experiment by an authorized user
4. Sign the authorized user sheet to affirm that the above steps have been completed

Unauthorized Personnel

No unauthorized personnel may enter McCone 349 during laser operation unless accompanied by an authorized user. All visitors must be briefed on proper safety protocol and must wear appropriate laser protective eyewear located on the premises.

# Section 3 - Hazards

Laser

The Laser Quantum Gem Diode-Pumped Solid-State laser is a Class 4 laser. Severe eye damage (including blindness) and skin damage can result from direct beam and specular reflections.

***Eye damage can also result from diffuse reflections.***

Electrical

Electrical shock or electrocution could result from direct contact with high voltage.

Do not touch the electronics behind the QDM computer and monitors.

Chemical

N/A

Pressure Hazards

N/A

Other

N/A

# Section 4 - Hazard Controls

Laser

1. Only authorized personnel will operate lasers.
2. The laboratory doors will be closed and locked whenever a laser is operating.
3. During alignments, the laboratory doors will be closed, locked, and a sign posted stating “Laser alignment in progress. Do not enter. Laser Eye Protection required.”
4. Unauthorized personnel will be only allowed entry to the laboratory during laser operation with the supervision of an authorized user under the terms specified in section 2.
5. Laser eye protection (LEP) for sufficient protection against (list wavelengths used) nm is available and is located at (detail the location of where laser eye protection is in lab and also describes the different types of eyewear if multiple pairs are needed). Laser eye protection is required to be worn for all beam alignments/beam manipulations or anytime there is an open beam that exceeds the maximum permissible value.   
   **Please note: Laser Eye Protection is wavelength specific and proper section is critical**
6. Specular and diffuse reflections will be controlled using beam stops, beam barriers, beam housings and enclosures. All of these control methods must be in place during normal operation.
7. No jewelry or other reflective materials are to be worn while working with the Laser, especially on the hands and neck.
8. Personal in the laser lab should avoid bending over or otherwise putting their eyes at the level of the beam path while the laser is in operation.
9. Laser alignment must be performed only by following the steps outlined in the alignment procedure supplement or alignment section.
10. Perform physical surveys to determine if there are stray beams (specular or diffuse) emanating from each laser and its optics, and then document the beam surveys noting the location of stray beams and the measures taken to control them. Please indicate the method of documentation of the survey (checklist or log, etc.)
11. If the beam path must be changed significantly by relocating the laser or optics, all users must be notified of the change.
12. The same precautions that are taken for safe operation of the laser must also be followed when adjusting any of the optics in use with the apparatus.
13. When a new principal researcher/experimenter takes over use of the laser system, the new user must conduct a survey for unwanted stray or diffuse beams. Appropriate tools such as IR sensitive cards or IR viewer shall be used for locating the possibility of stray IR light.
14. Experimental end stations should be treated the same as the laser system with regards to the proceeding safety procedures.

Electrical

1. Only qualified personnel may perform all internal maintenance to the laser and more than one user must be present when performing said maintenance.

Chemical

N/A

Pressure Hazards

N/A

Complete required training:

* [**EHS 111 – Compressed Gas Safety**](https://jwas.ehs.berkeley.edu/lmsi?searchText=EHS%20111)
* [**EHS 112 – Pressure Safety Awareness**](https://jwas.ehs.berkeley.edu/lmsi?searchText=EHS%20112)

Other

N/A

# Section 5 - Normal Operation

1. Check the check in list in Appendix A.
2. Check the laser interlock is connected and the yellow light is on. Without this interlock the laser will not turn on.
3. Turn on the Dr. Meter power supply for the microwave amplifier. Push IN the green button and the grey button in the middle of the panel.
4. Turn on the microwave amplfiier.
5. Open RemoteApp Laser control software. We only operate the laser via this software control. There is no hardware switch for the laser.
6. Click “connect” button under panel “Connection”. You should now see temperature readings to be about room temperature for both the PSU and the laser. Check if these temperatures make sense. If they are giving unreasonable values, it means the connection failed to establish. Try to toggle the “connection” button on and off a few times until the connection is active and stable.
7. Put on laser protection eye wear!
8. Click the “On” button under Laser Enable section. The laser will ramp up to the current set from by the middle panel.
9. Make sure you have laser eyewear, then check that you do have a beam coming out of the generator box.
10. Usually one does not need to align the entire beam path before starting an experiment. One only needs to center the beam on the diamond using the knobs on the top mirror by gently turning them back and forth.
11. Start up the QDM front facing software and start your experiments!
12. Enter QDM log entry in the lab notebook, noting date, laser power, sample, experiment specifics.

# Section 6 - Emergency Procedures

Laser accidents

Follow the steps outlined in the Procedure for Laser Accidents in Appendix B.

Power outage

If there is a power outage, turn off the laser to avoid a hazardous situation when power is restored.

# Appendix A - Checklist for using the QDM

Check in

* Door is closed and all personnel are wearing the appropriate laser protective eyewear
* Turn on the laser warning sign box
* Inspect the apparatus for any blockages or apparent misalignment
* Confirm that the beam path is set up to hit the sample properly
* Ensure that all beam enclosures and /or beam stops are placed properly in the work area
* Record laser energy in the logbook
* During the run, ensure that the laser is hitting the sample correctly
* Record any anomalous behavior in the logbook

Check out

* Shut off the laser

# Appendix B – Procedure for Laser Accidents

In the event of a laser accident

1. Ensure that the laser is shut off
2. Ensure the safety of personnel (first aid, evacuation, etc.) as needed   
   **Note — If an eye injury is suspected, have the injured person keep his/her head upright and still to reduce bleeding in the eye. A physician should evaluate laser injuries as soon as possible**
   * Obtain medical assistance for anyone who may be injured
   * If there is a fire, pull the alarm, and contact the fire department by calling **9-911** from a campus phone, or **510-642-3333** from a cell phone.  
     **Do not fight the fire unless it is very small and you have been trained in fire fighting techniques**
3. Inform the Office of Environment Health, & Safety (EH&S) as soon as possible

During Business hours

Call EH&S at **510-642-3073**

* + For Urgent Response, press 1
  + For all other calls, press 0 to leave a voicemail

After Business Hours

* + For Emergencies
    - Call **9-911** from a campus phone or
    - Call **510-642-3333** from a cell phone
  + For all other calls, press 0 to leave a voicemail

1. Inform Nick Swanson-Hysell and Yiming Zhang as soon as possible. If there is an injury, Nick Swanson-Hysell will need to submit a report of injury to the Worker’s Compensation Office.
2. After the incident, do not resume use of the laser system until the Non-Ionizing Radiation Safety Committee has reviewed the incident and approved the resumption of research.

# Appendix C - Alignment Procedures

Pre-Alignment Safety

1. Turn on the “Laser Alignment in Progress” notice sign outside the curtain of the lab before beginning any alignment procedure.
2. Check that the laser curtain is securely closed with no gaps.
3. Only authorized personnel are allowed in the laser lab during alignment.
4. All personnel in the room must wear the appropriate laser protective eyewear during alignment.
5. To reduce accidental reflections, watches, rings, dangling badges, and other reflective jewelry or materials must be taken off before any alignment activity begins.
6. Alignment should only be performed when there are at least two authorized users present who have been trained to respond to a laser safety emergency.
7. Check for and remove any foreign objects in the beam path other than safety controls such as beam blocks. Remove all unnecessary equipment, tools, and combustible materials from the laser table and immediate area to minimize the possibility of stray reflections and non-beam accidents.

General Alignment Safety Concerns

1. Use of non-reflective alignment tools should be considered. When reflective tools are required, be mindful to keep tools out of the beam path.
2. Never allow the beam to propagate beyond the point to which you have aligned and always be aware of the full beam path.
3. Always block the beam upstream when inserting/removing anything into/from the beam path, such as alignment irises.
4. Use a pair of index cards when checking the alignment of the beam so that you never have to leave the beam unblocked to move a card past a mirror.
5. As alignment proceeds down the table, a beam block should always be placed downstream in a position to catch the beam directly after the pair of mirrors being aligned, preventing the beam from propagating through an unaligned path.
6. Be aware that all transmissive optics generate back reflections and some reflective optics have substantial leak through. When working with these components be sure to track, block, and record all stray beams. This is a particular concern with filters (We currently use both ND and Bandpass filters), which generate strong specular reflections that can propagate back up stream a long way before diverging off the beam path due to very slight miss alignments. When such a reflection travels back upstream and encounters a beam splitting optic a new beam path can be formed in an unexpected direction.
7. When working with focusing elements, it is important to be aware that there may be sufficient intensity at the focus to burn skin and/or ignite combustible materials, such as index cards. At sufficiently high powers the focus may create plasma in the air resulting in a loud “popping” noise at the repetition rate of the laser, a glowing white spot at the focus where nonlinear optical processes are occurring, and the creation of ozone that smells like electric discharge. This can be disconcerting when unexpected. If this occurs simply block the beam upstream from the focusing element and either reduce the power of the beam or change the focusing element to a less tightly focusing optic.

External Optics

1. Beam path diagram:

A collage of a machine

Description automatically generated

1. Ensure that all users are wearing appropriate laser protective eyewear, warning signs are posted, make sure the warning light box is on, and laboratory doors are closed. Check that the laser path will be blocked.
2. Start up RemoteApp Laser Control software, establish the connection, enter 10mW for laser power (full power is 500 mW for operations) for alignment. You should be able to see the beam while wearing the OD3 laser goggles.

A screenshot of a computer

Description automatically generated

1. Once the beam going upward is aligned correctly, you should be able to see a small faint green dot on the tilted mirror.
2. Make sure to find the final beam spot on the sample stage. Usually, you do not need to move the fixed mirrors (1,2) on the optics table. You only need to adjust the z position of the mirror on the collar (3) which is on the vibration dampening cylinder.
3. Once the height of the mirror on the cylinder is adjusted correctly, and that the final beam spot is on the sample stage near or on the diamond, keep adjusting so that the beam eventually sits on the diamond.
4. Turn up the beam current to full power (500 mW).
5. Open up Camera\_Tester.vi and begin acquiring image.A computer screen shot of a computer

   Description automatically generated
6. Adjust the exposure time so that the brightest pixels saturate the scalebar.
7. Adjust the mirror positions and tilt so that the brightest part of the beam is at the center of the field of view (shown below).

A screenshot of a computer

Description automatically generated

1. Turn off the laser.
2. Check that ALL laser beam enclosure and /or beam stops are in place.

# Training Documentation

Authorized Users

By signing below, I agree that I have read and understood the Standard Operating Procedures for the QDM laser.

|  |  |  |  |
| --- | --- | --- | --- |
| **Printed Name** | **Signature** | **Date** | **PI Initial** |
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