Methods of Laser Frequency Stabilization

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Resonant Faraday rotation on alkali metals can be used to monitor the polarization of dense spin-polarized helium-3 targets. If spin exchange optical pumping is used to polarize the helium-3 nuclei, sparse amounts of Rb and K will be present in the target. Tuning external-cavity diode lasers to the D2 transitions of Rb or K maximizes the rotation of linearly polarized light due to the Faraday effect; which allowed measurement of small magnetic fields produced by the spin-polarized nuclei. To accomplish this goal, the laser frequencies must remain stable over long periods of time due to various environmental changes. We performed diagnostic interferometry to determine the rate of frequency drift and to locate the D2 transition frequencies via custom methods of automation on data acquisition and laser parameter control. Then, using the doppler free absorption spectrum of Rb or K as a feedback mechanism, a lock-in technique was used to generate an error signal and a PID feedback system allowed us to minimize the frequency drift of our ECDL to provide sufficient laser frequency stability for the Faraday rotation experiment.

Nomenclature

ECDL External Cavity Diode Laser

1 Toptica ECDL

In order to exert precise control over an external cavity diode laser it is important to understand the internal mechanisms responsible for a beam's wavelength. [1] The goal of these lasers is to provide narrow emission linewidth, precise wavelength selection, and stability over the course of longer experiments. A bare laser diode however delivers a broad range of wavelengths. Immediately following the diode are a series of wavelength selection optics. These include, a resonant cavity and a blazed grating in the Littrow configuration. A grating in the Littrow configuration light differently depending on their wavelength according to the relationship:

$$2\sin\theta_{in} = m\frac{\lambda}{d} \tag{1}$$

Where m is the reflection order (in most cases the first order is used) and d is the grating's spacing (distance between ridges). The Littrow configuration uses the blazed grating to reflect only a desired wavelength exactly towards the incident beam. This back-reflection is sent back into the laser resonator, and is amplified over as it reflects back and forth in the cavity. Part of this amplified beam will pass through an output coupler. The cavity size also influences the wavelengths amplified. In the same way a Fabry-Perot Interferometer only passes through light of a particular set of wavelengths, this resonator will also select wavelengths. We exert control over the wavelength by changing the grating angle by fractions of a degree using a piezoelectric actuator, a small crystal that expands and contracts with the voltage across it. The piezoelectric actuator in the Toptica ECDL accepts voltages in a range from 0V - 150 V. When the actuator moves the grating, a new Littrow angle reflects a new wavelength back towards the resonator, and results in a new output wavelength. Over the whole range of voltage inputs we found a tuning range of less than a 10th of a nanometer. The laser also affords users the ability to coarsely tune the grating, with a hex key. This nets us a range of 40 nm, from 765 nm to 805 nm. Well within many of Rubidium and Potassium's atomic transitions.

2 Fabry-Perot Interferometry

An interferometer is no more than two partially transparent mirrors creating a cavity. The distance between these mirrors creates a resonant cavity which constructively interferes on a set of wavelengths. Our interferometer uses two concave mirrors. The optical path in such a case is takes on 4 times the mirror spacing. Therefore, the possible wavelengths are those which have integer multiples equal to four

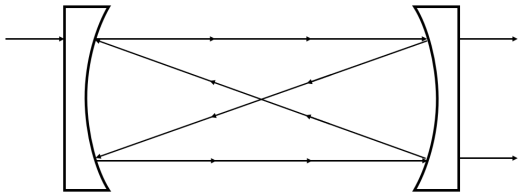

Fig. 1. Ray diagram of a confocal cavity

times the mirror spacing.

$$n\lambda = L \tag{2}$$

A ray diagram of the design is straightforward enough, and worth noting the four part cycle within the cavity. The right mirror in the diagram has a transmittivity of around 0.01. If then light is to make 100 cycles through the hourglass shaped path, only wavelengths that satisfy equation 2 will constructively interfere and become amplified adequately to pass through the output mirror.

Our setup takes the resonance chamber on step further by affixing a piezoelectric actuator to one of the mirrors. Controlling the distance between the mirrors allows control over the wavelength selected. Furthermore, such a selection can be made quickly and continuously, in a process known as scanning. With a stationary beam, sweeping a mirror through a wide will create a flash of light when the light is able to constructively interfere. There may be multiple flashes as the mirror hits different nodes (we typically swept through 3 nodes). Repeatedly sweeping creates regular flashes. With a function generator, we control the spacing of the mirrors precisely, and analyze the timing of the flashes on an oscilloscope to find very small changes in the wavelength.

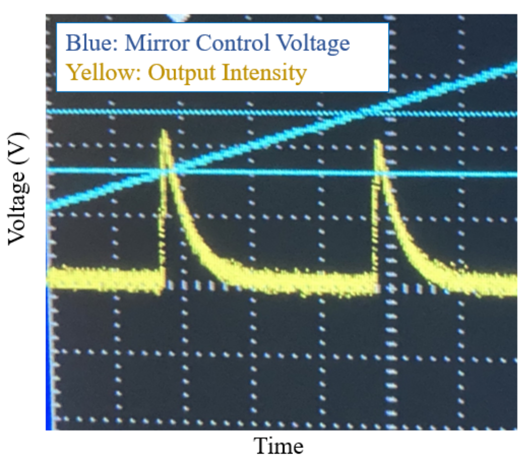

Fig. 2. Scanning Fabry-Perot Interferometer

The spacing between two peaks is known, and the movement of a peak can be tracked over the course of hours. This became our first look into the stability of the DL pro's stability.

3 Very Very Very Very Very Very Very Very Very Very Very Long Heading

The heading is boldface with upper and lower case letters. If the heading should run into more than one line, the run-over is not left-flushed.

3.1 Second-Level Heading

The next level of heading is also boldface with upper and lower case letters. The heading is flushed left with the left margin. The spacing to the next heading is two line spaces.

3.1.1 Third-Level Heading.

The third-level of heading follows the style of the second-level heading.

4 Use of SI Units

An ASME paper should use SI units. When preference is given to SI units, the U.S. customary units may be given in parentheses or omitted. When U.S. customary units are given preference, the SI equivalent *shall* be provided in parentheses or in a supplementary table.

5 Footnotes[1]

Footnotes are referenced with superscript numerals and are numbered consecutively from 1 to the end of the paper[2]. Footnotes should appear at the bottom of the column in which they are referenced.

6 Mathematics

Equations should be numbered consecutively beginning with (1) to the end of the paper, including any appendices. The number should be enclosed in parentheses and set flush right in the column on the same line as the equation. An extra line of space should be left above and below a displayed equation or formula. LaTeX can automatically keep track of equation numbers in the paper and format almost any equation imaginable. An example is shown in Eqn. (3). The number of a referenced equation in the text should be preceded by Eqn. unless the reference starts a sentence in which case Eqn. should be expanded to Equation.

$$f(t) = \int_{0_+}^{t} F(t)dt + \frac{dg(t)}{dt} \tag{3}$$

[1] Examine the input file, asme2ej.tex, to see how a footnote is given in a head.

[2] Avoid footnotes if at all possible.

Fig. 3. The caption of a single sentence does not have period at the end

7 Figures

All figures should be positioned at the top of the page where possible. All figures should be numbered consecutively and centered under the figure as shown in Fig. 3. All text within the figure should be no smaller than 7 pt. There should be a minimum two line spaces between figures and text. The number of a referenced figure or table in the text should be preceded by Fig. or Tab. respectively unless the reference starts a sentence in which case Fig. or Tab. should be expanded to Figure or Table.

In the following subsections, I have inserted figures that have been provided by authors in order to demonstrate what to avoid. In each case the authors provided figures that are 3.25in wide and 600dpi in the .tif graphics format. The papers containing these figures have been held from production due to their poor quality.

7.1 The 1st Example of Bad Figure

In order to place the figure in this template using MSWord, select Insert Picture from File, and use wrapping that is top and bottom. Make sure the figure is 3.25in wide.

Figure ‘4 was taken from a recent paper that was held from publication, because the text is fuzzy and unreadable. It was probably obtained by taking a screen shot of the computer output of the authors software. This means the original figure was 72dpi (dots per inch) on a computer screen. There is no way to improve the quality such a low resolution figure.

In order to understand how poor the quality of this figure is, please zoom in slightly, say to 200%. Notice that while the font of the paper is clear at this size, the font in the figures is fuzzy and blurred. It is impossible to make out the small symbol beside the numbers along the abscissa of the graph. Now consider the labels Time and Cost. They are clearly in fonts larger that the text of the article, yet the pixilation or rasterization, associated with low resolution is obvious. This figure must be regenerated at higher resolution to ensure quality presentation.

The poor quality of this figure is immediately obvious on the printed page, and reduces the impact of the research contribution of the paper, and in fact detracts from the perceived quality of the journal itself.

7.2 The 2nd Example of Bad Figure

Figure 5 demonstrates a common problem that arises when a figure is scaled down fit a single column width of 3.25in. The original figure had labels that were readable at full size, but become unreadable when scaled to half size. This figure also suffers from poor resolution as is seen in the jagged lines the ovals that form the chain.

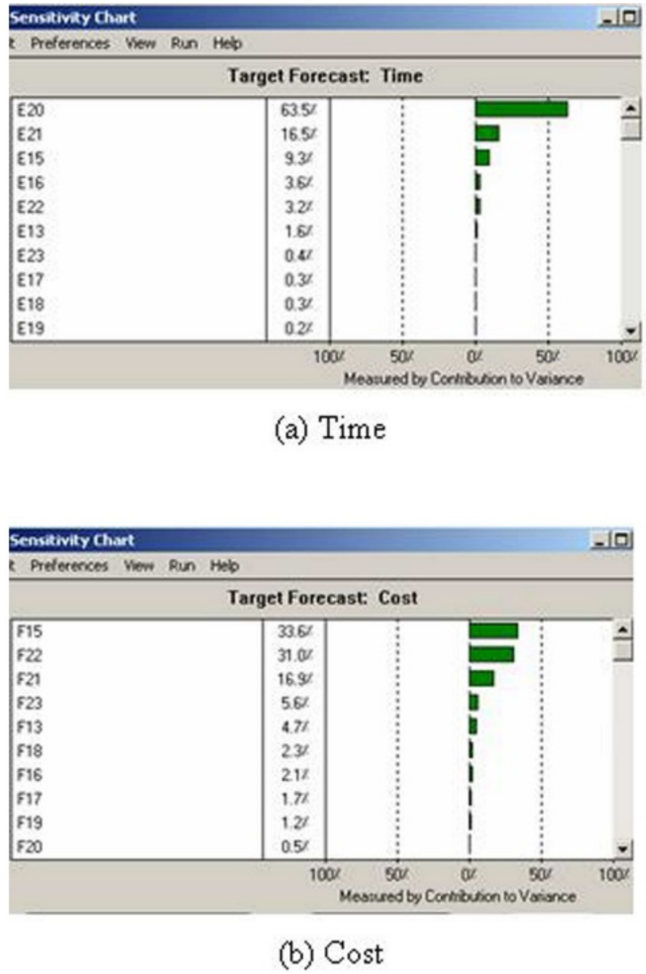

Fig. 4. Example taken from a paper that was held from production because the image quality is poor. ASME sets figures captions in 8pt, Helvetica Bold.

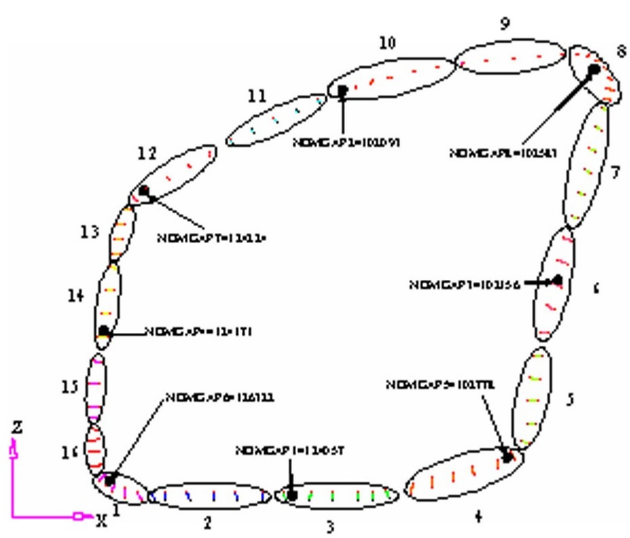

Fig. 5. While this figures is easily readable at a double column width of 6.5in, when it is shrunk to 3.25in column width the text is unreadable. This paper was held from production.

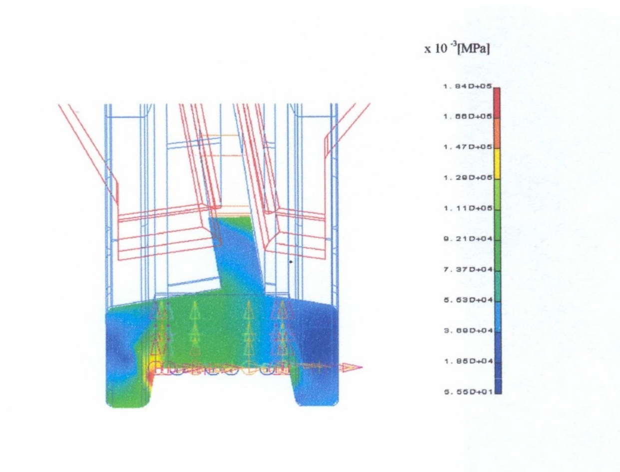

Fig. 6. Another example of a figure with unreadable text. Even when the paper was expanded to double column width the text as shown in Fig. 7 was of such low quality that the paper was held from production.

This problem can be addressed by increasing the size of the figure to a double column width of 6.5in, so the text is readable. But this will not improve the line pixilation, and a large low resolution figure is less desirable than a small one. This also significantly expands the length of the paper, and may cause it to exceed the JMD nine page limit. Additional pages require page charges of $200 per page. It is best to regenerate the figure at the resolution that ensures a quality presentation.

7.3 The 3rd Example of Bad Figure

An author provided the high resolution image in Fig. 6 that was sized to a single column width of 3.25in. Upon seeing the poor quality of the text, the publisher scaled the image to double column width as shown in Fig. 7 at which point it took half of a page. The publisher went on to do this for all eight figures generating four pages of figures that the author did not expect. ASME stopped production of the paper even with the larger figures due to the pixilation of the font.

Clearly the text in this figure is unreadable, and it is doubtful that the author can print the output in a way that it is readable. This is a problem that the author must solve, not the publisher.

As you might expect, I have many more examples, but in the end the author is the best judge of what is needed in each figure. ASME simply requires that the image meet a minimum standard for font and line quality, specifically the font should be the appropriate size and not be blurred or pixilated, and that lines should be the appropriate weight and have minimal, preferably no, pixilation or rasterization.

8 Tables

All tables should be numbered consecutively and centered above the table as shown in Table 1. The body of the table should be no smaller than 7 pt. There should be a minimum two line spaces between tables and text.

Table 1. Figure and table captions do not end with a period

Example	Time	Cost
1	12.5	$1,000
2	24	$2,000

9 Citing References

The ASME reference format is defined in the authors kit provided by the ASME. The format is:

> *Text Citation*. Within the text, references should be cited in numerical order according to their order of appearance. The numbered reference citation should be enclosed in brackets.

The references must appear in the paper in the order that they were cited. In addition, multiple citations (3 or more in the same brackets) must appear as a " [1-3]". A complete definition of the ASME reference format can be found in the ASME manual [1].

The bibliography style required by the ASME is unsorted with entries appearing in the order in which the citations appear. If that were the only specification, the standard BIBTEX unsrt bibliography style could be used. Unfortunately, the bibliography style required by the ASME has additional requirements (last name followed by first name, periodical volume in boldface, periodical number inside parentheses, etc.) that are not part of the unsrt style. Therefore, to get ASME bibliography formatting, you must use the `asmems4.bst` bibliography style file with BIBTEX. This file is not part of the standard BibTeX distribution so you'll need to place the file someplace where LaTeX can find it (one possibility is in the same location as the file being typeset).

With LATEX/BIBTEX, LATEX uses the citation format set by the class file and writes the citation information into the .aux file associated with the LATEX source. BIBTEX reads the .aux file and matches the citations to the entries in the bibliographic data base file specified in the LATEX source file by the `\bibliography` command. BIBTEX then writes the bibliography in accordance with the rules in the bibliography .bst style file to a .bbl file which LATEX merges with the source text. A good description of the use of BIBTEX can be found in [2, 3] (see how two references are handled?). The following is an example of how three or more references [1–3] show up using the `asmems4.bst` bibliography style file in conjunction with the `asme2ej.cls` class file. Here are some more [4–14] which can be used to describe almost any sort of reference.

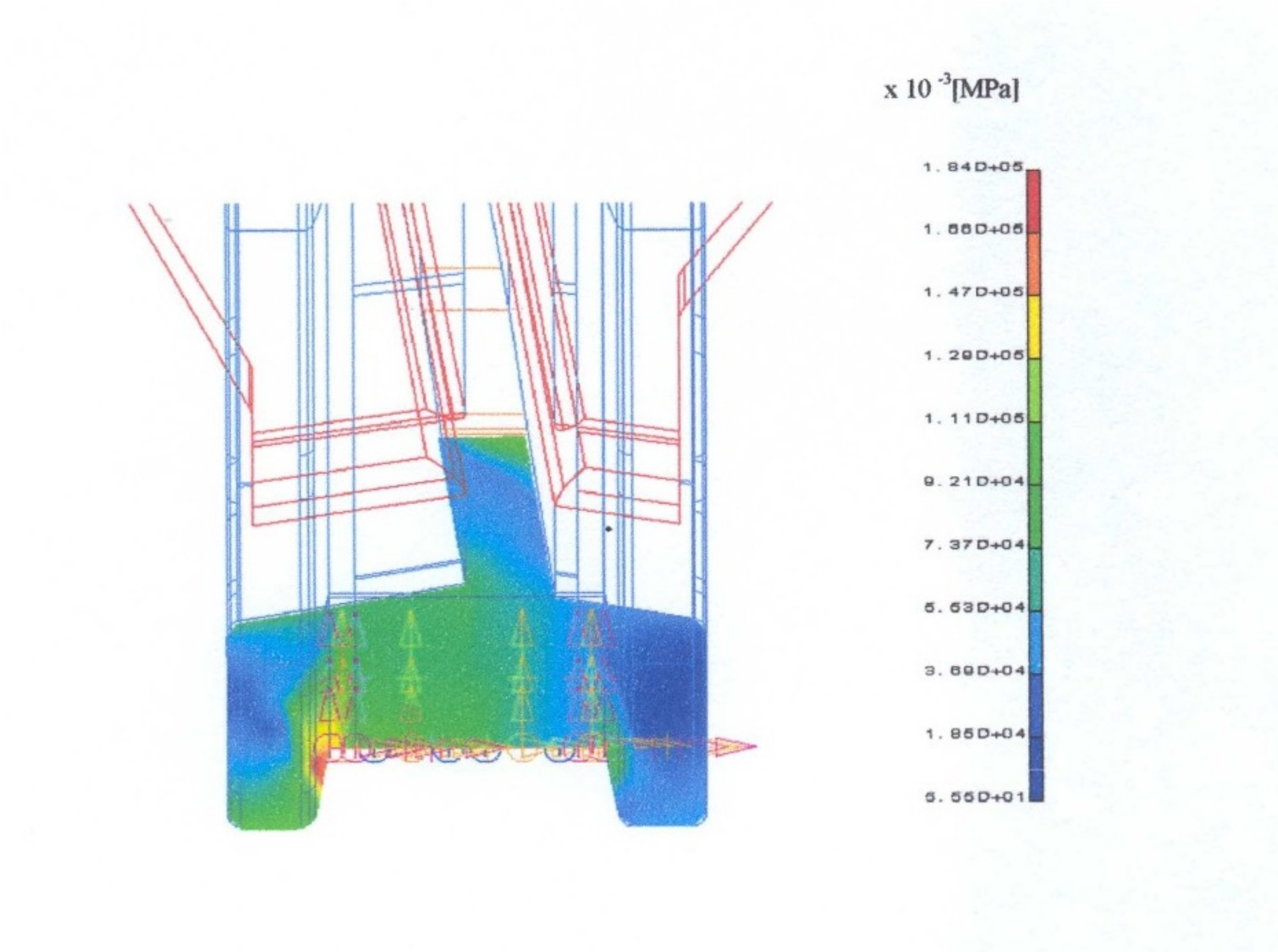

Fig. 7. A figure expanded to double column width the text from Figure 6

10 Conclusions

The only way to ensure that your figures are presented in the ASME Journal of Mechanical Design in the way you feel is appropriate and meets the requirement for quality presentation is for you to prepare a double column version of the paper in a form similar to that used by the Journal.

This gives you the opportunity to ensure that the figures are sized appropriately, in particular that the labels are readable and match the size of the text in the journal, and that the line weights and resolutions have no pixilation or rasterization. Poor quality figures are immediately obvious on the printed page, and this detracts from the perceived quality of the journal.

I am pleased to provide advice on how to improve any figure, but this effort must start with a two-column version of the manuscript. Thank you in advance for your patience with this effort, it will ensure quality presentation of your research contributions.

11 Discussions

This template is not yet ASME journal paper format compliant at this point. More specifically, the following features are not ASME format compliant.

1. The format for the title, author, and abstract in the cover page.
2. The font for title should be 24 pt Helvetica bold.

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Acknowledgements

ASME Technical Publications provided the format specifications for the Journal of Mechanical Design, though they are not easy to reproduce. It is their commitment to ensuring quality figures in every issue of JMD that motivates this effort to have authors review the presentation of their figures.

Thanks go to D. E. Knuth and L. Lamport for developing the wonderful word processing software packages TEX and LATEX. We would like to thank Ken Sprott, Kirk van Katwyk, and Matt Campbell for fixing bugs in the ASME style file `asme2ej.cls`, and Geoff Shiflett for creating ASME bibliography stype file `asmems4.bst`.

References

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Appendix A: Head of First Appendix

Avoid Appendices if possible.

Appendix B: Head of Second Appendix

Subsection head in appendix

The equation counter is not reset in an appendix and the numbers will follow one continual sequence from the beginning of the article to the very end as shown in the following example.

$$a = b + c. \tag{4}$$