**Optics Notes Index** PhL last update: 2.20.03

**1. Optics Notes from Jackson, etc.** (11/28/02, 18 pages, no figures) These are notes I took while doing selected readings in Jackson's E&M book and the optics books of Carlson and Goodman borrowed from the SLC library. The goal was just to learn basic areas of study that seemed related to my floater visibility problem. I have copies of the first four chapters of Goodman's book on Fourier Optics, and much of this document talks about those chapters. The general thread is Kirchhoff, Sommerfeld, then Fresnel, then Fraunhofer, and finally wave optics in lens systems. The key relevant idea for me at this time is diffraction from an opaque disk, this being the simplest possible model for the floater shadow on the retina.

2. **Floaters inside the Focal Point**. (12/1/02, 2 pages). Goodman, in his Chapter 5 on wave optics, talks about putting image transparencies at various points in a lens system, and tracing what happens to those images. His case (c) puts the image transparency between lens and focal point, so this seemed relevant to where floaters might exist. The coning-down quadratic wavefront from the lens converts a hole in a screen (the image transparency) into a Fourier Transform Airy pattern right in the immediate focal plane, thus doing "Fraunhofer" without having to go a long z distance. This is because that coning-down beam cancels the non-Fourier phase in the Fresnel integral. I was thinking that maybe the hard-edged disk might pass through its soft Airy phase at the focal plane, and then re-appear as a disk an equal distance to the right of the focal plane and this might align with the retina. That would imply somehow that free space can image things just as a lens does, I now think the idea is wrong. First Babinet ideas.

At this point I went to New York for about 2 weeks: Evelyn, Cod, Lee, Greenwich, NR & home.

3. **The Field of a Disk** (12/24/02→12/28/02, 13 pages, contents on 1st page). Why are there rings? This contains my own Babinet "proof", and then has plots showing 1 - Airy interference on the retina. The main point is that the hole just makes a diffraction pattern, but a disk makes a total field that is diffraction pattern "plus" (really minus) the initial plane wave. These two components have strong interference which severely modifies the Airy pattern almost beyond recognition. I now call this notion "Babinet/Airy". I show Excel plots of same printed from Sheet 2 of "airy plots.xls". Estimate that eye resolution is 27μ, from half-tone test. The last section of this document is "how the eye lens affects Babinet/Airy diffraction", and I think it is a bit wobbly.

**4. Notes on Wyant's Fresnel Diffraction Lecture.** (12/28/02, 3 pages, see printed PDF). A side trip into the topic of Fresnel Zones and Zone Plates. Also, some use of FFT to compute the integrals in Mathematica.

**5. Scalar vs Vector & Jones Gaussian Beam: waist as focal spot** (12/29/02, 2 pages, see printed PDF). (1) Comment on why exp(ikr)/r does not solve vector equations. (2) Review of Jones' PDF doc which derives the Gaussian Beam and interprets it a bit.

**6. Matrix Optics Tutorial Notes** (12/29/02, 2 pages, see printed HTM). The tutorial describes the little 2x2 matrix formalism used to analyze lens systems, including fat lenses, etc. Talks about principle points, cardinal points, etc. Treats the telescope.

**7. Matrix Optics and Gaussian Beams** (12/29/02, 4 pages). (1) The first part of this paper takes a simple A,B,C,D 2x2 matrix and shows how it alters radius of curvature of a wavefront; (2) this subject is related to the transformation of the q-parameter of a Gaussian Beam, with emphasis on where beams have their waists. The motivation here is to understand why parallel light from a distant source does not have infinite intensity at the focal point, you get a waist there instead. Recall that exp(ikr/r) fails for small r, and the Gaussian beam is "what happens" at small r.

**7A. Gaussian Beams and Questions of the Focal Point** (1/29/03, 2p -- file missing but printed OK) Here I worry about exp(ikr)/r and BYU and the vector wave equation, and also review the Gaussian Beam derivation in on of my PDF documents.

**8. Index of Optics Related PDF Files** (12/30/02, 3 pages). I have so many things now, in the downloads area by the way, that they required their own little index document. Storing this in both places. Subjects include Bessel Beams, slot antennas, Airy moonlight, numeric aperture, mirages, GRIN lens, saltus, gaussian beams, matrix optics, microscopes, flow in vitreous, etc.

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**9. Floater Optics Revisited** (12/31/02, huge wad in separate binder section, 29 pages, contents on 1st page, plus 9 hand figures, occluded disk Excel calculation, off-axis hand Airy calculation + addendum, the Disk Babinet Integral, various XLS files )

This document covers intense floater "model building" work done over from 12/31/02 through 1/9/03. Although I did not end up with the ultimate theory of floaters, I did do very many things. And I got a theory that is at least semi-reasonable in that it explains: (1) why floaters I see have the general size that I see them have; (2) why they have rings despite incoherent sources; (3) why some have central bright spots. All the theory here models a floater as a 8 μ diameter flat opaque disk parallel to the retina plane, and makes use of Babinet's Principle to find the exact Fraunhofer field of the disk, using Airy for the hole.

Topics include: incoherent extended sources, off-axis Airy calculation, eye as compound optical system, a pure-geometry floater model with no diffraction ("floatergeometric.xls"), contrast sensitivity function of the eye (CSF), yard experiments on resolution, trolands and nits, floater-in-gravity issue, the "Disk Babinet Integral Theorem", geometric model modified to include rings, DLL to sum over many incoherent sources, "floater3.xls".

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**9A. Better Floater Radiation Models** ( 1/9/03, 1 page) In this short comment, I first thought that with a plane wave incident, the "direct Sommerfeld I attack" on the disk would have a log divergent integral, but then I realized that the phasor makes it converge after all.

**10. Some Recent Activities of Phil Lucht** (1/10/03, 2p) A summary of floater work done to this point, written for Orbtek visit. Indicates intentions for future work.

**11. Direct Sommerfeld Attack on the Disk** (1/11/03, 17 p 1 figure). This was an ambitious attempt to *directly* compute disk diffraction in Fraunhofer using the Som I diffraction formula. There were two motivations: (1) to try and confirm/verify the Babinet/Airy result; (2) to be able to perhaps add

transparency to the disk. I was able to write the integrals, and to show that they converge, but I could not do either the $\phi$ or the $\rho$ integral analytically! I was able to do some large-k limits using stationary phase, but this just gave a geometric-limit result. Review is on page 10. Used a point source instead of plane wave, thinking it was needed for convergence, no longer think it is needed. Thought about partial disk transparency. Problem here is the infinite integrations which block effective approximations.

**12. More Disk Attack** (1/18/03, 6 pages). Continues thread of previous paper. Instead of large-k, tried doing a small-$\theta$ approximation to the $\phi$ integration. This is doable, but then the $\rho$ integral cannot be done. See "Conclusion" of this line of effort on page 6. End of the road!

**13. Stationary Phase for a 2D integral** (1/19/03, 3 pages, MOVED TO MATH BINDER). Another spurt. Was wondering if I consider both integrals at the same time, maybe I could find a region of $\rho$-$\phi$ space to which the integration could be restricted and then done. But still, you are only going to get the large-k asymptotic limit.

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**14. Radiation by Dielectric and Metal Objects** (1/20/03→1/27/02, 18 pages, contents on 1st page). I failed trying to apply Kirchhoff to the disk, but radiation theory remedies this problem completely. Here I studied Jackson's radiation techniques and then applied them to various dielectric objects including a disk, a sphere, and a spherical shell. In doing so, I was able to verify the earlier Babinet/Airy result, and am able to handle transparency in the sense that the diffraction is a proportional to (n-1), the index. Also, I think the results apply at wide angle as well as in the Fraunhofer limit. A much better way to go. My real-time type-setting skills are improving with Word. After all, it has been "a while".

**14A. Scattering from Dielectric Objects without ignoring radiated field ( 1/28/03, 3 pages)** Here I noticed that, when using the electric-dipole or maybe the "Portis" approximation for radiated field, if you compute the field close to or within the dielectric radiator, the radiated field is huge compared to the incident field, which is inconsistent with the initial assumption that this is not the case. The resolution is that the formulas used for radiated field do not apply at such short distances, you need a fuller solution.

**15. Radiation Approach versus Scattering Approach to Dielectric Sphere** (2/6/03, 11 p, conclusions on first page). For sphere large relative to $\lambda$, your only real choices are Mie scattering or numeric integration! Portis results are only good for small spheres, but larger than very small spheres!

**16. Scattering from the dielectric sphere ("first attempt")** (2/5/03, updated 2/19/03, 8 pages). This was my multipole attempt to match the boundary conditions and derive the historic 1908 Mie scattering coefficients. The calculation is very messy, and I hoped to find a place to confirm my results, but I was never able to find results in this formalism. I had to use Jackson's polarization states, other people do it differently. This leads into the various versions of Vector Spherical Harmonics (VSH) that people use. Notes on that subject are in the E&M binder, since they are pretty general. // In my update, I reconciled results here with those found later, see #20 below.

**17. Mie Scattering and the M and N Functions** (2/14/03, 8 pages, MOVED TO VSH SECTION OF EM BINDER). I kept seeing these functions in various papers, and found out what they were here. They turn out to be nothing new in the VSH world I learned about from Carleton and Jackson.

**18. Learning about Mie Scattering** (2/8/03 - 2/14/03, 3 p). History and references, Marriott trip. It turns out this is very much larger subject than I at first thought. It has many applications today, and has had many variations to adapt to more complex problems. E&M research is not all done and finished! I do have (downloads area) a nice Mie program which seems to do the far-zone scattering patterns from which you get the rainbows and glories and coronas. For the moment, this paper brings my research efforts to a close.

**19. Papers about Mie Scattering and various VSH functions.**

- **4** page clip with mysterious plane wave expansion, and quote of the historic Mie coefficients
- 3 page clip from library which has similar stuff but hints at more complexity, has references
- a funny Wolfram Research note on VSH but has good references. ( located in VSH section EM)

**20. Second Attempt at Mie Scattering Coefficients.** Using the M and N vector harmonics, I state the expansion of a plane wave for simple x-polarization, and then do the full Mie calculation, following the Krugel PDF approach. All details are here, but maybe summary document (next) is better place to review things. In any event, the resulting coefficients agree with those quoted in Krugel and other places.

**21. A Summary of the Mie Scattering Calculation.** Here I tried to give an overview of the problem and its solution, not just for dielectric sphere but for arbitrary linear isotropic $\mu$ and $\varepsilon$. So finally this problem is solved, but I have not done any calculations yet using the full solution.