Azure Hansen
WISE Physics major; Class of 07; Laser Teaching Center group, '04-present;
NSF-REU Fellow (Summers '04-'05);
NIST-SURF Fellow (Summer '06)

Research Mentors: Drs. Harold Metcalf & John Noé,
Laser Teaching Center;
Department of Physics & Astronomy

Researcher of the Month - December 2006

About Azure

If you want to know what wavelength Azure is on, [~ 500 nm]. . . or are interested in finding out what it's like to grow up in a dome ["living in cylindrical coordinates, phi and rho. . . rather than Cartesian coordinates, xyz"], or want to know just how *transformative* undergraduate research can be**,** meet Azure Hansen, Class of '07!

As a freshman, Azure took *WISE 187: Introduction to Research* and had a fortuitous rotation in the Laser Teaching Center (LTC), a hands-on educational facility in the Department of Physics and Astronomy, that has become her home away from home:
"In the Laser Teaching Center, you have to find your own project and match it to your interests. We found this paper about observing extra solar planets, that *just happened to be sitting on Dr. Noé's desk and it changed my life.* I worked on that during the spring semester of my freshman year, just learning what these light beams are. It takes a while to understand them. It's in a field called singular optics. . . .. . it was a completely new world to me."

That next summer, Azure continued working with her Stony Brook mentors, Drs. Harold Metcalf and John Noé and participated in Stony Brook's Research Experiences for Undergraduates (REU) Physics program sponsored by the National Science Foundation (NSF). At the closing symposium, Azure gave a presentation entitled: "An Interferometric Tool for Observing Extrasolar Planets." A couple months later, Azure gave a talk entitled "Making Light with a Twist" at the Undergraduate Research Symposium (organized by Prof. Metcalf) at Frontiers in Optics 2004, a joint annual meeting of the Optical Society of America (OSA) and the Division of Laser Science of the American Physical Society (APS-DLS) held in Rochester, NY—the "optics capital of the country", and close to where Azure grew up in Marion, New York.

Azure continued working at the Laser Teaching Center during the academic year, and presented a poster at URECA's 2005 Celebration in the spring. In summer 2005, she participated in another NSF-funded REU program, this time at the University of Rochester 's Institute of Optics, working under the mentorship of Prof. Nicholas Bigelow on a project entitled: "An Optical Vortex as a Trap for a Bose-Einstein Condensate." This work formed the basis for a second appearance at the *Frontiers in Optics* undergraduate symposium where Azure presented "Trapping a Bose-Einstein Condensate with a Laguerre-Gaussian Beam" (October 2005, Tuscon, Arizona). Azure continued working in the Laser Teaching Center during her junior year, again presented at URECA's Celebration, and was awarded the National Institutes of Standards & Technology's (NIST) Summer Undergraduate Research Fellowship (SURF) to work in summer '06 in Gaithersburg, Maryland with the Atomic Physics Division, Laser Cooling Group: Dr. Kristian Helmerson and 1997 Physics Nobelist Dr. William Phillips supervised the NIST-SURF project, entitled "An Optical Vortex-Based Azimuthal Lattice for Rotating a Bose-Einstein Condensate." Azure presented her NIST-SURF research in Gaithersburg, MD (August 2006); at the recent annual *Frontiers in Optics* conference (October 2006, Rochester, NY), and also gave an hour-long Atomic & Molecular Optics (AMO) seminar given here on campus, a talk attended by many graduate students, post docs and faculty in the Department of Physics & Astronomy. It is worth noting that Azure was the first undergraduate asked to present a full length seminar at this forum!

Azure truly has found her niche and community at the Laser Teaching Center . She can be found there at all hours of the day or night, not only working on her own research projects but also assisting many other students who work there with their optical tweezers set-ups, including high school students as well as graduate students.

Azure is currently applying to graduate programs where she plans to pursue a PhD in experimental physics with a concentration in quantum optics and ultra-cold atomic physics. She credits both her parents for early on instilling a love of nature and encouraging her in all scientific pursuits (from observing nature outdoors, including the night sky. . . to watching *Nova*. . . o providing genuine, scientific answers to all her curious questions as a child), though her father died when she was only 10. Azure's first elementary school fair project, in 4th grade, actually related to optics! Azure also loves hiking and being outdoors, adores cats (and all animals really!), and relishes travelling to new places—something which she hopes to be able to do more through physics research. She also is active in WISE recruitment efforts and hopes to get more students engaged in a love of physics. Below are some excerpts of her interview with Karen Kernan, URECA Director .

The Interview

***Karen:* Tell me about your start in the Laser Teaching Center (LTC), your first involvement with research here on campus.**

Azure: In the Laser Teaching Center, you have to find your own project and match it to your interests. . . I wanted to do something related to astronomy and optics. We found this paper about observing extra solar planets, which are planets outside of our solar system, around distant stars, using a special light beam called an optical vortex. And so that paper just happened to be sitting on Dr. Noé's desk and *it changed my life.* . . I worked on that during the spring semester of my freshman year, just learning what these light beams are. They're pretty weird; it takes a while to understand them. It's in a field called singular optics. I worked on that and had a poster at URECA. And that was exciting because it was my first presentation out in the real research world.

We didn't do research in my high school. We didn't have research programs. I did science fair projects in elementary school, but we didn't have research. So it was a completely new world to me. . .In my high school, I was the only one interested in physics. I was one of very few interested in science in general. So that was a new fun experience, just working with other people who were interested in science. . . .working with the high school students too and other undergraduates.

Is it true that you have continuously worked at the LTC since freshman year?
I'm there everyday basically. I help with the WISE high school program, and the WISE freshman program and with the students that are doing research now. We have graduate students too. I was helping a little bit with optical tweezers set-up that the graduate student was working on. He was working with a high school student who wants to use optical vortices in the tweezers. So it's all just interconnected stuff. It's really a close community of people working on very different projects in the lab but everybody helps each other and learns from each other.

The Laser Teaching Center is really unique in that most students doing research at Stony Brook go into a lab and they contribute to a project that's ongoing, that the professor is publishing papers on But in the Laser Teaching Center, it's just a bunch of students from high school to graduate students that are working on projects that they basically think of and direct with the help of Dr. Noé. And they really set how far it's going to go and what's it's going to relate to. Right now we have someone interested in astronomy and cosmology. He's doing something modelling gravitational lensing using this gradiated index refraction tank, a fish tank basically. He calls it "fish tank relativity." . . It's probably 10 dollars worth of materials. A lot of neat math though and a lot of advanced concepts. In the LTC, you're really totally understanding your entire project versus. . . doing a small part of a big project. Basically, you can do whatever you want within optics.

The Laser Teaching website is great. I believe you had to do a research journal for the LTC website, didn't you?
Yes, there's s a very comprehensive website. And we have to hand code all the HTML which is a big deal. It's good to see how things work. That's our philosophy. No black boxes. You want to see how everything works and get down to the fundamentals. Everyone keeps a research journal so you can see really how people's ideas progress and also what else goes on in the lab. If we go to a talk, I'll write it up in the journal. . . There's a lot of pictures too. And we recently made an "Explore Optics!!", a list of websites you can visit to learn about optics. We show it to kids we're giving tours to, through High School WISE. We're trying to just get people interested in optics.

What are you working on right now ? How much does it relate to what you did freshman year?
I've diverged in some ways through the years but pretty much it's all related to what happened freshman year, and all my other research experiences since then—which is really unique. And it's been really fun. Last semester, I started working on making these wave plates to make circular polarized light using cellophane. That was initially to lock a laser to a specific frequency. . . I'm doing a report now in my advanced quantum class on geometric phase, which is a property of quantum and classical systems where if you change the parameters of the system in a closed loop. . . so you rotate the polarization and certain conditions and rotate it back to where you started.. . . it won't be the same system even though you think it should be . .Optics is good because you can really understand so many different things using it. It's easy to get a laser and some fibers and lenses and see what 's going. So you can really understand a lot of phenomena which is a fun thing about optics.

At the URECA Celebrations each spring, you've done several hands-on demonstrations. How did you transition to presenting at off-campus meetings?
After my first summer here, after freshman year, I went to a conference from the Optical Society of America and the American Physical Society's Division of Laser Science. It's called Frontiers in Optics, or the Annual Meeting. Hal Metcalf organizes a symposium on undergraduate research that's just for undergraduates doing research in optics from all over the country. And so I gave a talk there—my sophomore year—after my first summer of doing research. I gave a talk there which was really fun but even more exciting was that I got to meet the guy whose paper I read initially that got me into this field. His name is Grover Swartlander. He's at the University of Arizona in Tuscon. I got to meet him and talk to him about his research. . . it was amazing to meet these people. You read their papers 50 times, you read all their papers. . . and then you meet them!

You also started doing some research off-campus fairly early on, didn't you?
Yes. After my freshman year, I worked at the University of Rochester in Nick Bigelow's cooling and trapping group [in an REU program]. My job there was to build a laser to make these optical vortex beams to use on the Bose Einstein Condensate or BEC. It's a separate state of matter that's ultra cold, nanokelvin; atoms that are cooled to that temperature have really interesting properties. I got to learn about the BEC, and how that's achieved. Nanokelvin is really, really cold. It's a whole new field. Atomic physics was new to me then. Since then, I've fallen in love with it. That's what I want to do.

I know recently you spent a summer in Maryland, at NIST. Tell me a little about this experience.
NIST is National Institute of Standards and Technology. It used to be the National Bureau of Standards. It was founded to standardize a lot of different things. The second, the meter, the kilogram. . . things that you wouldn't think about—like, fire department hoses (which at one time, were all different sizes.) . . . It was about an hour from the heart of DC on the train, the Metro. . . . The SURF program had 120 kids from all over the country in all different areas. My roommate was a chemistry major, we had engineer majors, biology majors, computer science. . . everything. A lot of NIST is really very applied. One of my friends was working on standardizing chili pepper's hotness. Other people were working on top secret things. Some were working on things that will be patented.

I was in the laser cooling group in the Atomic Physics division doing basic research. Again, I was working on the BEC and optical vortices. This time we were trying to make an optical lattice using optical vortices that have never been done before. . . . NIST was really fun.. . . working with the post docs and permanent faculty and visiting scientists. . . At Rochester, I had worked with graduate students who were a couple of years older. At NIST, the post docs were from all over the world. I worked most closely with someone who was from Paris. In my lab alone, there was someone from Denmark, Korea, and India. It's just great. That's one of the things about physics that's so fun. . . and in all sciences. You really meet a lot of people from all over the world, and you get to travel . .That 's a fun thing about physics.

When you came back this fall, you were asked to give a seminar about your summer research experience. I was told you were the first undergraduate ever asked to do this. Did you find it intimidating?
In our group, in the Atomic & Molecular Optics group at Stony Brook, the students always give a talk after their summer experiences. We always have a couple of undergrads somewhere. So they give a talk at group meeting which is an informal thing that happens on Friday afternoons. Everybody talks about problems and how to solve them. But we had a hole in the AMO seminar schedule. So Hal Metcalf and Tom Bergeman suggested I give an hour-long talk. It was quite the opportunity. It was fun. I think the most interesting thing about giving a talk or poster is getting a question that you never thought of, and it just throws you. . . it can give you a new perspective on things. Writing a paper or talk really helps to condense your ideas so that you really know what you understand and where your gaps are.

I remember you worked some great images of cats into your presentation.
I miss my cats a lot. I love animals. At school, there are no animals. My sister is studying to be a vet tech, and she gets to spend a lot of time with animals at school, but I don't have anything. I have photons. But the cats in my talk … it was just because it was a great image that related to the subject… Actually, cats are a recurring theme in physics. There's a Schrödinger cat problem…….the whole cat thing started in quantum mechanics.

After you finished, several professors commented on your poise in speaking, and in being very clear about what you do and do not know. Is that skill something that's taken a while to develop?
One thing about being associated with the Laser Teaching Center specifically I guess is that you get to be around a lot of people, a lot of physicists. And that's really important. You get to really know what people do all day, how they interact with each other, how their minds work. That's really important I think in becoming a scientist, just being around them, going to dinner with them. If you're just going to lectures all day.....that's not really what scientists do. Learning how scientists think is really important.

And so I've had a lot of opportunities to interact with all these wonderful scientists, in these different optics and atomic physics fields, to speak with seminar speakers, at meetings, and here at Stony Brook. That's really helped in understanding how a scientist's mind works. Also, going to the colloquia is really important. I don't think enough undergraduates are aware of their value; they just don't go...In my first physics class at Stony Brook, Gene Sprouse encouraged us to go to colloquia.. . There are also the astronomy open nights on Friday nights. Then, in sophomore year I started going to AMO seminars. That became my specialty.

You've been to quite a few talks, colloquia, lectures, etc. , and met lots of other students from other universities too. Do you feel like you have a solid background in physics, looking back now on the past few years?
I was surprised at how well I could understand a lot of the talks. You get to this point where things just kind of sink in and then you can build on things from there. You really have to start with a foundation, and work hard to get that foundation. Then you can really understand. It's surprising, it's amazing. A lot of it was way over my head of course, but it's a field where you can really understand a lot.

Tell me about your mentors. What have you learned from them? What is like working with these very different personalities that you've interacted with?
The easiest person to talk about is Bill Phillips, one of my mentors this summer at NIST. And he's famous for really questioning everything. So we'd have group meetings or seminars, and the speaker wouldn't get past the first slide or two before Bill was questioning them on something.. . I remember once we had an hour and a half discussion on Van der Waals' forces. You talk about it in physics classes. But really understanding something.. there's a lot of arguments, or rather debate, between people who have different interpretations of things...just really getting down to the basic physics and really understanding things. It's just a lot of questioning. Bill's really famous for that...

And Prof. Metcalf?
Hal is the same way in a way. In a class I'm taking right now, he'll tell these stories about the early days of laser cooling. ...Laser cooling has what Hal calls 'Murphy's law violations.' Things shouldn't work but they do. It's really interesting. Also, Hal also knows absolutely everyone in the universe, it seems. Science is more than just sitting in a lab, a dark cold lab (if it's an optics lab)...tweaking knobs, taking data, and writing papers. It's really about meeting these people, and seeing the connections both in different areas of physics, but also between different people. People...their careers may diverge..but there's always the underlying physics that will connect you back. These meetings we go to are like family reunions. Every year your family keeps growing, exponentially it seems. . . . Hal is big into networking, and doing physics based on friendships, evolving with friendships. That's a fun thing about physics. You meet all these people who are as obsessed with physics as you are. And you feed off each other. And suddenly it's 3 oclock in the morning and you're still in the lab!

How would you describe Dr. Noé who helped you get your start in this field?
His philosophy, to every student that we get, is to do whatever is best for them, really get in their heads, see what makes them interested, and then to find what he can do to help them become passionate about physics and do well in their research. So personalizing education is really important to him. We work together with the high school WISE programs, and again, we don't have any set curriculum.

The Laser Teaching Center is a good environment for people who are self motivated and interested, genuinely interested. No one is going to tell you what to do in that kind of environment. .John Noé will come in on weekends, he'll sit with students talking about physics, working on the experiment till twelve o'clock at night. He's very dedicated both to physics and to the people behind the physics. . . At the LTC, we're just trying to understand the physics better and get people motivated so they can go further in physics if they want to ...

For you, what was the best day and the worst day of research?
There are a lot of good days. Some of the worst days are when you're sitting in the dark and it's cold. It's always cold in optics labs. You're making things that are nanokelvin.. . it's always cold, and you're freezing all the time. I remember this one time at Rochester when I was trying to build this amplifier for a laser and the tolerances on the machining and the heat dissipation were . . giving us a lot of trouble. Sometimes you just feel like it's never going to work... . At NIST too, there was a period when I was building the interferometer. . .when there was so much noise. I couln't get the resolution I wanted in controlling the interferometer and I thought, this is never going to work. . . But then I said to myself, wait, this is physics, it's fun...you just need to try something else. Talk to other people about the problem. . . . In optics, you're working with things like a wavelength that's 600 nanometers. You

have to adjust things at such precision… You're sitting there tweaking knobs for hours. You have all these knobs and there are so many parameters that you have to change to get something to work. Hundreds of knobs that you need to tweak...So when it does work it's just amazing! Hundreds of knobs and they're in exactly in the right place.

Does something ever work and you don't know why?
That's half the fun. There some quote that the best moments in science are not "Eureka" but when someone says "That's weird." There's something going on that you don't understand…sometimes it's something exciting that you didn't expect at all.

How do you feel your research has prepared you for the future?
Doing research has basically been the highlight, or the essence of college because it makes you understand things at a deeper level. But also it gives you something to shoot for. Junior level mechanics is boring, but you know that there are all these other interesting things that you'll need mechanics for to understand. My [classmates] who don't do research or go to the colloquia sometimes can't see the big picture as much, which is really important in physics. You also need all the little nitty gritty details. Research has also helped by giving me more intuition in courses that you'd think aren't related. Everything is so connected. If you get better in one area, it will help in another area. My first semester working in ultracold physics, I didn't have any background in BECs. But after having had quantum mechanics, working in BECs the second summer, I could understand a lot more what was going on in the lab. This made we want to take solid state physics, which you wouldn't think is related to BEC. It's all just intricately connected.

Was the opportunity to do research one of the things that initially appealed to you about Stony Brook?
I wanted to go to Stony Brook because it had a really strong physics department and a lot going on in physics. And because of the WISE program. My high school was really small. Going to a big school where there are more red lights here than in my town was scary. WISE made that community smaller, and helped me get those first mentors who have helped me throughout.

What advice would you give to an incoming student? And to other students about research?
I'd said to talk to other people about the opportunities. To you, their undergraduate directors, to older students. Getting involved early is really important. Some of my classmates still haven't done any research and they're at a loss now. They want to go to graduate school, but they don't have any idea in what field. .My friends who have started doing research have either loved it or decided it's not what they want to do. And that's helpful too.

Also, research is fun. It s not like going to some horrible job every day . If you're a physicist, you're working all these expensive toys. Lasers are cool. And just putting your knowledge to work to do something that no one has ever done before, that's really exciting. It's like exploring, like the old explorers, charting unknown territory. It's like that but science.

How did you first develop a love of physics?
Science was always my thing all through school. When I was little, it was mostly life science that interested me. We had a lot of science toys, legos, chemistry kits. I always liked understanding the world. My father was a chemist, so that helped. We'd ask questions and actually get answers—what lightning was, what the states of matter are. It was natural in our house to watch science shows. NOVA was a big part of my childhood. So we were encouraged to pursue whatever interests we had, and I gravitated towards science.

When I did a report on stars in 8th grade and read a book by Stephen Hawking about cosmology and astrophysics..I decided that I really wanted to do physics. In 8th grade science, physics and chemistry, we could describe things using math which was really exciting. I took every science class in my high school and outside. I knew I wanted to do science.

It's a perfect life for me I think.