N-Dimensional Engineering

Founded by

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Abstract

If the field of view of a camera does not follow the rotation of the Earth, such that the image being captured moves relative to the camera sensor, then the image can become blurred, or the stars in the field of view appear as streaks rather than distinct bright points in the picture. On Alt-Az telescope mounts, in addition to tracking the object being photographed, the star field rotation must be corrected by a patent pending field co-rotating corrector, which is a device that rotates the camera in the same direction as the star field rotation. Distinct from prior art, neither user settings, user-operated software, computer connectivity, nor access to the internet are required for the present device to function anywhere in the world that GPS reception is available. Ubiquitous third party electronics measure environmental variables and perform calculations within unique new firmware, enabling operation of the device in an automated manner.

The plan is to manufacture a heavy duty Alt-Az fork mount which is adjustable and basically "one size fits all." The mount will come with an adjustable brightness touch screen, with a preinstalled Linux OS, along with proprietary control software with image acquisition capability included. Much of this has been developed already, but in order to further develop the technology, the company needs funding -- plain and simple. There is quite a bit of equity in the IP alone, already. To generate revenue quickly, the first product will be a field co-rotating correction device, with patent pending technology that allows operation without cords or cables. This is essentially accomplished with a 9 DoF IMU/magnetometer taking measurements, while an algorithm determines rate of rotation. Once revenue picks up, the mount is planned to be the second product. Eventually, quite a few other products are in the works, but this is the plan for the first few years. The open source code I posted on github is GNU public license and free for the community, except for the updated PID algorithm, which is a registered copyright. The code for the mount is quite different and much more well-developed, yet proprietary. Hardware and software will change over the long haul, but a great deal of IP, hardware, and software has been developed already.

Figure 1. *Streaking of an image when field rotation is not used on an Alt-Az mount.*

Background

The burgeoning hobby of astrophotography is big business in the post-Covid era. In fact, the CES (Consumer Electronics Show) 2021 Innovation Award went to the French company Vaonis for their smart telescope named the Vespera. Their business model is substantially different from that of N-Dimensional Technologies, LLC, but what both companies understand is that interest in astrophotography is booming, yet it involves quite a steep learning curve. Making astronomy and astrophotography more accessible to the public can only have positive impact on science and society.

Finding an observing target can be challenging enough for the uninitiated, but taking long exposure images of a star field that is moving and magnified through a telescope poses several challenges. In order to avoid blurring or streaking, the field of view, hereafter referred to as the star field, must be "tracked." A well-functioning automated equatorial mount will track the star field

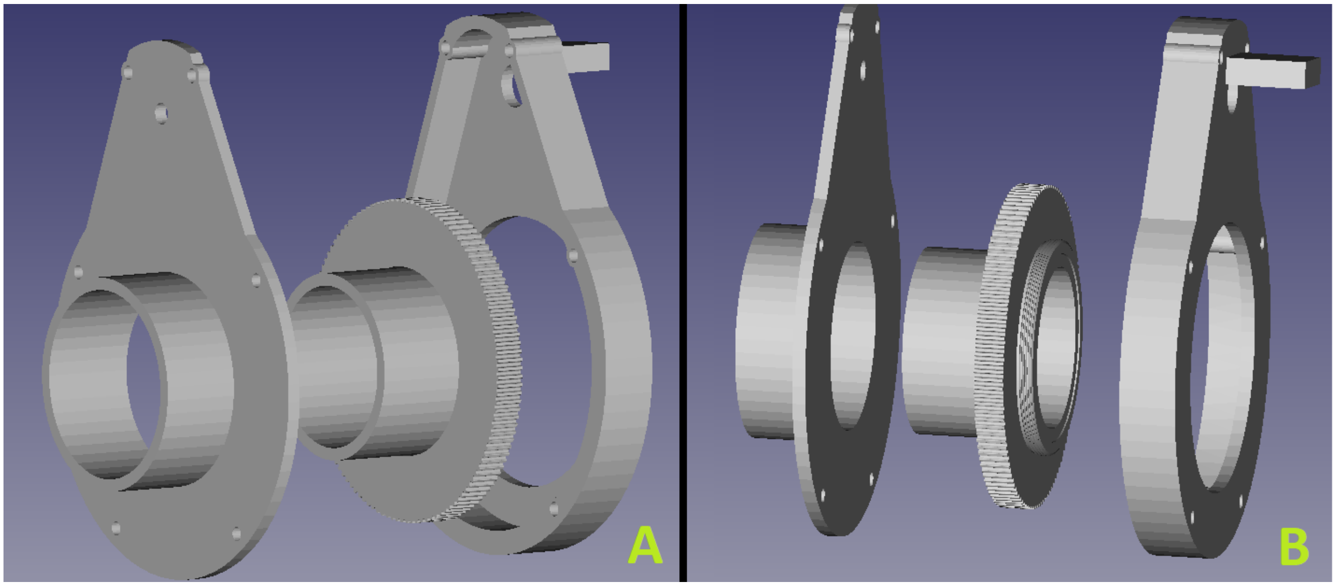

Figure 2. *Two views of a 3-piece structure, where (A) is a view from the left, and (B) is a view from the right.*

without problem, allowing the user to take long exposure images. The problem is that equatorial mounts (often called German equatorial mounts) are often cumbersome, expensive, weight-limited, and difficult to use. Alternatively, an Alt-Az or Altitude-Azimuth telescope mount is much simpler to operate; however, even when automated with tracking capability, an Alt-Az mount cannot account for the apparent relative rotation of the star field, called "field rotation" (Fig. 1), since that degree of freedom is inherently stationary in its design, unless it is propped up at an awkward angle on a wedge. To account for field rotation, practitioners occasionally (although they are becoming increasingly popular) employ what is known as a "field rotator," "field rotation corrector," or "field de-rotator." Here, it will be referred to as a field co-rotating corrector, and the design by N-Dimensional Technologies, LLC is patent pending (non-provisional patent application #17/303,486).

Existing field co-rotating correctors are mechanical devices which rotate the camera attached to a telescope on an Alt-Az mount. They tend to be driven by a motor and drive train, such that extremely slow rates of rotation can be achieved, ranging from approximately -140 to 0 to 140 arcseconds per sidereal second, with the sign indicating direction, which depends on which hemisphere the observer is viewing the star field. Existing field co-rotating correctors are controlled by either Ascom or Indi

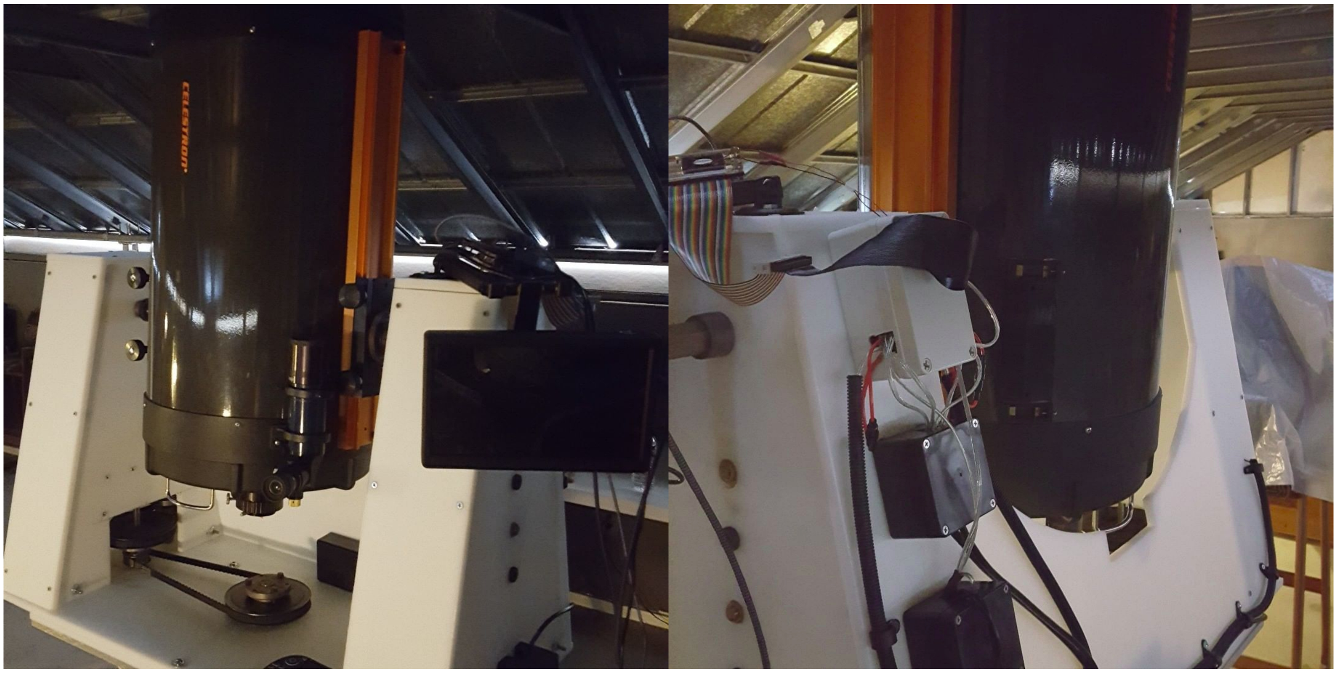

Figure 3. *The front and back of N-Dimensional Technology, LLC's prototype Alt-Az telescope mount.*

drivers and interface with the tracking software of the mount, since rotation rate is dependent upon which direction the mount is pointed. The present invention eliminates the need for this dependency.

Detailed Description

The equation for the rate of field rotation is the following:

$$rate = \frac{15\cos(\phi)\cos(A)}{\sin(z)}, \qquad \text{Eq. 1}$$

where φ is the latitude of the observer, A is the azimuth angle, and z is the zenith distance angle (90 degrees minus the altitude angle) [1, 2]. Incidentally, all of these quantities can be measured using an inertial measurement unit, a GPS receiver, a magnetometer, and a few calculations. GPS signal can provide the latitude φ, azimuth angle A can be calculated from measured magnetic north and modeled declination angle, zenith distance angle can be calculated by solving for the normal of the plane of the incline of the inertial measurement unit.

Embedded electronics perform the calculations and drive the mechanical system. The drive train is driven by a stepper motor which runs on a rechargeable battery. Figure 2 displays an example of the

Figure 4. *Image of the Eagle Nebula (Pillars of Creation or Messier 16) taken with an extremely narrow field of view, as proof of concept that the mount points with a level of accuracy appropriate for professional quality data acquisition. Data was acquired on June 13, 2020, as one data file, taken with 120 second exposure. This new image is property of © John Emil Petersen III, January 20, 2021.*

machinations of a version of the device. The key component is the middle piece which appears to be a cog in Fig. 2(A), while in Fig. 2(B), threads can be seen on the other side for attaching a camera. Thus, the center piece is driven while attached to the camera, and the other two pieces serve other purposes, including structure. The left-most piece is fitted into a telescope tube directly.

In addition to the field co-rotating corrector, which is still in the late design phase, N-Dimensional Engineering has developed a fully functioning Alt-Az telescope mount prototype which tracks accurately, with a level of pointing accuracy appropriate for high quality data acquisition, using high precision encoders. Three provisional utility patents on the Alt-Az mount have been submitted, and the design is entirely original and novel, while the proprietary software is original, including a registered copyrighted PID algorithm. Figure 4 displays the full capability of the mount.

Wider fields make for more aesthetic pictures, but a narrow field such as this exhibits the capability of the mount more effectively. Since perturbations or disturbances are magnified greatly when focusing on a narrow field, it is clear that the mount is extremely capable of acquiring high quality data for the professional or amateur alike. Field Rotation, which is minimal at this point in the sky, this time of year (June 13, 2020), and at this latitude was not accounted or corrected for during this image acquisition. The following relevant details of the data acquisition are as follows:

- Field of View: 16.87' x 11.49' (Equivalent to 1012.2" x 689.4")
- Resolution: 0.24"/pixel (not including the 2x bin for both X and Y)
- Area: 193.8 sq'
- Focal length: 3910mm
- Focal ratio: f/11
- One image -- 120 second exposure
- Taken near Johnson City, Texas

[1] Smart, W.M., *Textbook on Spherical Astronomy* (Sixth Edition, reprinted), Cambridge University Press (Cambridge, 1979).

[2] Trueblood, M. and Genet, R.M., *Telescope Control* (Second English Edition), Willmann-Bell, Inc. (Richmond, 1997).

Market Sector Analysis

According to Global Info Research, the global amateur telescope market value was greater than $218 million in 2019. It is predicted to approach nearly $300 million in 2025. Most of the amateur telescope market is located in The United States, Canada, Mexico, Germany, France, United Kingdom, Russia, Italy, China, Japan, Korea, India, Southeast Asia, Australia, Brazil and Saudi Arabia. However,

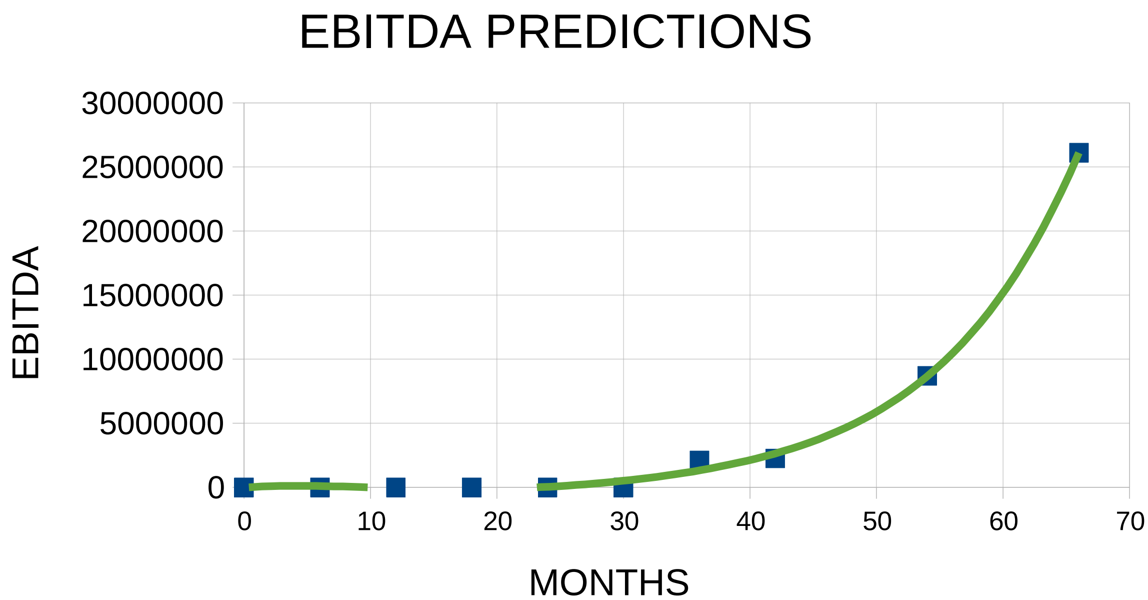

Figure 5. *EBITDA predictions for the first 66 months. Month 60, at which valuation is calculated, is an interpolation from the fitted estimate.*

N-Dimensional Engineering will focus its marketing campaign efforts on North America and Europe.

Due to the great precision, accuracy, and heavy duty nature of the current Alt-Az mount prototype, N-Dimensional Engineering may pursue markets within the professional realm of astronomy, as well. Uninhibited by the limited budgets of amateurs, we could reasonably pursue high dollar contracts with professional astronomers controlling significant funding via large grant budgets, effectively scaling capability of our products to suit our clients' needs.

In addition to the mount, our patent pending (USPTO application #62/704,840) field co-rotating corrector, which we call the Alpha Field Corrector™. Field co-rotating correction devices are rather new to the astronomy accessory market, so it is difficult to evaluate market size or potential market share of the Alpha Field Corrector™. That being said, our model has some extraordinary advantages over its competitors, as the device requires neither wires nor external software and exhibits simplicity at its finest.

Some competing devices include Optec's various Pyxis Camera Field Rotators, Optec's Gemini Focusing Rotator, William Optics' Camera Angle Rotator, Primalucelab's Robotic Camera Rotator, and Pegasus Astro's Falcon Rotator. Clearly, if there is room in the market for this many competing models, our version with significant advantages will sell quite well. One of the foremost pioneers of earthbound astrophotography, Al Kelly, a retired NASA employee, has agreed to field test the prototype and give his recommendation upon evaluating satisfactory performance.

The price range of such devices typically ranges from $600 to $1400. N-Dimensional Engineering estimates a price target of $1200 for the Alpha Field Corrector™ . Raw material cost of the current design is approximately $400. Assembly, loading firmware, and Q&A testing are estimated to cost approximately $100 in labor, resulting in $700 EBITDA per unit, neglecting office space and utilities. Within the first 12 months of operation after initial product launch, at the end of year 3, we expect to sell at least 500 units, doubling our market share the following year with at least 1000 units, resulting in revenue approaching $700,000 in year two. Year three is expected to see even greater revenue growth.

The large margin item in the lineup will be the Alt-Az telescope mount with patent pending technology on each axis (applications #63/199,613 and #63/199,589), along with another provisional utility patent on the entire apparatus itself (application #63/199,614) which is featured in the video on http://n-dtech.com. The mount is adjustable, such that telescopes up to 150 pounds and diameters ranging from 6-18 inches can be mounted effectively. The apparatus is the sole property of N-Dimensional Engineering , designed and constructed by John Emil Petersen III, Ph.D. Our product was designed, prototyped, and will be manufactured in the USA. In the lower price bracket, most competitors are overseas companies in Asia. In the higher price bracket, US companies such as Astro-Physics, Software Bisque, and Planewave Instruments manufacture premium mounts. However, as far as we are aware, only Planewave makes Alt-Az mounts, and many of these sell for upwards of $10,000. Our current design, which is based on our three provisional utility patents, has a raw material cost of approximately $1,200 (yet the 2nd version of the prototype and the final product are predicted to cost $1600). As mentioned previously, the design can be modified and/or upgraded to suit the various needs of amateurs or professionals – in addition to the standard model, custom mounts may be available for custom prices.

Milestones

- Month 6 – finish building structures (manufacturing and Q&A facility)
- Month 9 – receive order for newly designed PCB microcontrollers
- Month 11 – complete first Alpha Field Corrector™ prototype
- Month 14 – complete second version Alt-Az mount prototype
- Month 16 – complete second version Alpha Field Corrector™ prototype
- Month 22 – complete both product development cycles
- Month 24 – Arizona Science and Astronomy Expo – Sky & Telescope (Mid-November 2023)
- Month 24 – Black Friday launch of both products on website, followed shortly after by deals presumably made with online retailers at the trade show (High Point Scientific, Astronomics, etc.)
- Month 30 – First revenue report

Financials

According to preliminary marketing data (previous section), predicted EBITDA in month 60 is approximately $15 million. Using a multiple of 15, as is customary for the industry, valuation of the business comes out to approximately $225 million. A $5 million investment for 10% equity would yield an annualized ROI of approximately 40% per year over a 5 year period – netting $22.5 million at the end of year 5 (over 400% ROI), assuming an equitable exit strategy.

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https://www.researchgate.net/profile/John-Petersen-Iii
https://github.com/tarbalreboot
https://orcid.org/0000-0002-6907-8418

Professional Experience

Business Owner, Founder, and CEO **Jan 2018 –**
N-Dimensional Engineering (http://n-dtech.com)
∞ Developed robotic positioning system (mount) from scratch for Alt-Az telescopes
∞ Achieved a level of performance appropriate for professional data acquisition
∞ Secured intellectual property such that valuation exceeds $100 million
∞ https://www.tiktok.com/t/ZTRTc5E4w/ (Basic demonstration – robotics and control systems)

Research Associate **Jan 2012 – Dec 2017**
Texas State University, Department of Physics
∞ Calculated physical properties of novel materials via quantum mechanical first-principles
∞ Utilized Linux high-performance computing clusters to compile, run, and/or write various scientific programs using C/C++, bash, and other programming languages
∞ Characterized structural and electronic properties of materials via x-ray diffraction, atomic force microscopy, and Hall measurements, often using LabView
∞ Presented original results at professional society conferences and in peer-reviewed journals

Teaching Assistant **Aug 2011 – May 2015**
Texas State University, Department of Physics
∞ Introduced students to fundamental laws of electrodynamics and basic electrical engineering principles, through theoretical lecture and practical demonstration
∞ Became exceptionally familiar with circuits and their components

Various independent contractor roles, including Financial Adviser **(2006-2011)**

Skills

∞ Demonstrated hard coding and mathematical modeling ability with C/C++, linking libraries
∞ Showcased systems engineering capability in the robotics, electrical, and mechanical engineering communities with both interpreted and compiled programming languages
∞ Seasoned scripting skills with bash, awk, and C#
∞ Well-practiced in both relational (SQL) and key-pair (non-SQL) development and query
∞ Developed several professional websites (html, css, and php)
∞ Versed in Linux and Windows, whether in the terminal, Visual Studio, or office suites
∞ Experienced at public speaking, as evidenced by professional society meetings
∞ Skilled in materials characterization by XRD, AFM, and Hall measurements
∞ Talented with both CAD and shop tools, bringing design to prototype

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https://www.researchgate.net/profile/John-Petersen-Iii
https://github.com/tarbalreboot
https://orcid.org/0000-0002-6907-8418

Education

PhD, Materials Science, Engineering, and Commercialization **Dec 2017**
Texas State University

“Impurities in Antiferromagnetic Transition-Metal Oxides – Symmetry and Optical Transitions”
https://digital.library.txstate.edu/handle/10877/6921?show=full
GPA: 3.74

Master of Science, Physics **May 2013**
Texas State University

“First Principles Study of Structural, Electronic, and Mechanical Properties of Lead Selenide and Lead Telluride”
https://digital.library.txstate.edu/handle/10877/4556?show=full
GPA: 3.13, Excellence in Graduate Research Award (May 2013)

Bachelor of Science, Physics **Dec 2010**
University of Texas at San Antonio

GPA: 3.34
- ∞ Co-founder and treasurer of local branch of Society of Physics Students
- ∞ Best Paper award at ABES Student Conference, 2010
- ∞ Dean’s list (multiple)
- ∞ Omicron Delta Kappa leadership honor society member

Bachelor of Arts, Liberal Arts **Aug 2005**
University of Texas at Austin

- ∞ Minor in Business Foundations
- ∞ Studied Business Spanish abroad at ESADE, in Barcelona, Spain (summer 2002)

Oral Presentations at National Conferences

APS March Meeting, New Orleans, LA **Mar 2017**
Ab Initio study on structural, electronic, magnetic and dielectric properties of LSNO within Density Functional Perturbation Theory, J. Petersen, et al.
http://meetings.aps.org/link/BAPS.2017.MAR.A8.2

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https://github.com/tarbalreboot
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APS March Meeting, Baltimore, MD **Mar 2016**
First Principles Study of Oxygen Vacancies and Iron Impurities on Electrical and Optical Properties of NiO, J. Petersen, et al.
http://meetings.aps.org/link/BAPS.2016.MAR.Y30.9

Selected Publications (Reverse Chronological)

9. Symmetry Considerations on Band Filling and First Optical Transition in NiO, J. Petersen, et al., **The European Physical Journal B** (**2019**) 92: 232.
https://doi.org/10.1140/epjb/e2019-100363-5

8. Spontaneous symmetry breaking and electronic and dielectric properties in commensurate $La_{7/4}Sr_{1/4}CuO_4$ and $La_{5/3}Sr_{1/3}NiO_4$, J. Petersen, et al., **Physical Review B** 97 (195129).
https://doi.org/10.1103/PhysRevB.97.195129

7. Carrier Lifetimes of Iodine-Doped CdMgTe/CdSeTe Double Heterostructures Grown by Molecular Beam Epitaxy, S. Sohal, et al., **Journal of Electronic Materials** 46 (9).
https://doi.org/10.1007/s11664-017-5646-y

6. Iodine Doping of CdTe and CdMgTe for Photovoltaic Applications, O.S. Ogedengbe, et al., **Journal of Electronic Materials** 46 (9).
https://doi.org/10.1007/s11664-017-5588-4

5. Effect of Free-Carrier Concentration and Optical Injection on Carrier Lifetimes in Undoped and Iodine Doped CdMgTe/ CdSeTe Double Heterostructures Grown by Molecular Beam Epitaxy, S. Sohal, et al., **Journal of Physics D Applied Physics** 49 (50).
http://stacks.iop.org/0022-3727/49/i=50/a=505104

4. Factors Influencing Photoluminescence and Photocarrier Lifetime in CdSeTe/CdMgTe Double heterostructures, C. Swartz, et al., **Journal of Applied Physics** 120 (16).
https://doi.org/10.1063/1.4966574

3. The Effect of Anisotropic Valleys on Phonon Scattering and the Magnetotransport Properties of n-Type PbTe, C. Swartz, et al., **Journal of Electronic Materials** 45 (1).
https://doi.org/10.1007/s11664-015-4184-8

2. Thermoelectric Properties of IV-VI-Based Heterostructures and Superlattices, P. Borges, et al., **Journal of Solid State Chemistry** 227 (123).
https://doi.org/10.1016/j.jssc.2015.03.027

1. Elastic and Mechanical Properties of Intrinsic and Doped PbSe and PbTe Studied by First-Principles, J. Petersen, et al., **Materials Chemistry and Physics** 146 (3).
https://doi.org/10.1016/j.matchemphys.2014.03.055

Referee with Physical Review Letters and Physical Review B