Exploration and Practice of Teaching Reform on Photoelectric Countermeasure Equipment

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Abstract. Through analyzing the current situation and existing problems of practical teaching of photoelectric countermeasure equipment, in order to improve the ability of trainees to take up their posts, satisfy the needs of military colleges teaching mode in the new era, we carried out research on the reform of practical teaching of optoelectronic countermeasure equipment, Optimized the integrated teaching content combining theory, experiment and project, and explored the comprehensive application mode of various teaching, scientific research and equipment platforms, It has formed a practical teaching system that meets the requirements of "being able to use, support, test and repair", It is abbreviated as "four skills", Practice has proved that it has achieved a good teaching results.

Keywords: engineering education reform · photoelectric Countermeasure equipment · practical teaching · comprehensive design experiment

1 Introduction

It is the goal of military academies to cultivate high-quality students to improve their ability to adapt to the posts of the army. The new military reform demands new and higher requirements for military academies. It is also an important part of the construction of high-quality post holding courses in our college. For many years, practical teaching has always been the weak point of engineering education in China [1]. Teachers generally do not attach enough importance to practical teaching, and they mainly use scientific education methods to teach engineering courses. One of the drawbacks of current engineering education is that it blindly emphasizes the teaching of existing knowledge [2]. For practical teaching, it is just the verification and application of some simple scientific principles. As long as students operate according to the experimental procedures in books, they can get certain data and conclusions. We have not established the main position of students in the teaching process, and there is a lack of thinking and research content for students. no enough practical teaching to train students to learn and think actively [3]. Photoelectric equipments principle and test maintenance is an important post practice course. There are two main problems in practical teaching. First, the teaching is mostly organized around the "single function and single equipment", lacking the

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comprehensive testing practice content considering the whole equipment; The second is the equipment practice teaching method of "emphasizing principle and neglecting design". The teaching methods tend to scientific education, using the methods of analysis and deduction. It is difficult to mobilize the students' active participation, and their thinking ability is not fully developed. It can be said that the current equipment practice teaching content and method still have a certain gap with the actual improvement of the students' ability.

In response to the above problems, we carried out research on the reform of practical teaching content of photoelectric equipments principle and test maintenance. Through the research, we further clarified the practical teaching objectives, reformed the practical teaching content, innovated the practical teaching mode, highlighted the designing, thinking and flexibility of the practical teaching, and explored the teaching mode of equipment principle, equipment application, and equipment test and maintenance, greatly promoting the core competence of equipment practice teaching in our college.

The "four skills" teaching scheme is show Fig. 1, we optimized the experimental content, and enhanced the design of the experiment on the basis of giving consideration to the comprehensiveness and integrity of the content [4], at the same time, the definition of teachers and students in the curriculum was clarified, through the careful design and strict implementation of the experimental plan, the students are encouraged to be bold and careful and actively participate, which improves the students' interest in learning, so as to better achieve the teaching goal of cultivating students' hands-on practical ability and scientific research innovation ability.

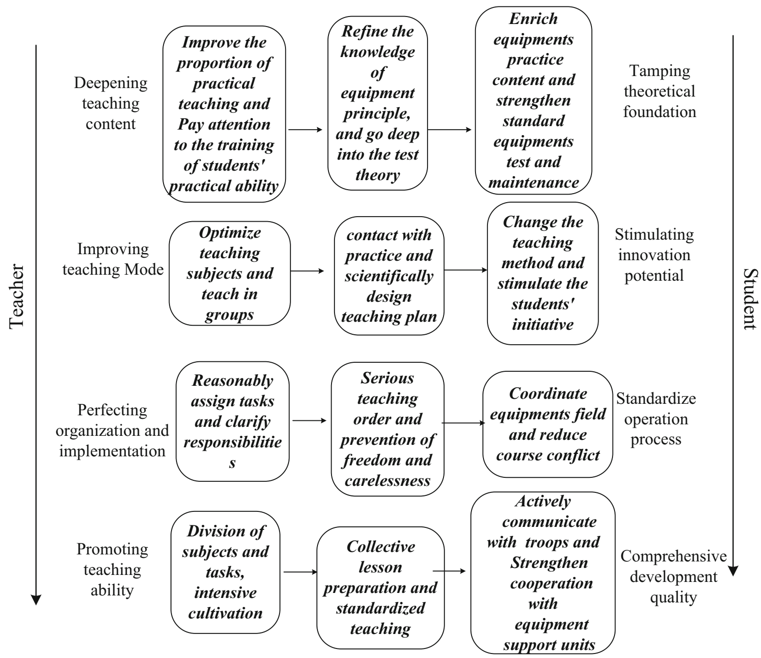

Fig. 1. Teaching scheme of photoelectric equipments principle and test maintenance

Table 1. Capability Matrix

Competency learning process	**four skills**			
	use	***support***	***test***	***repair***
Innovation awareness			●	●
Professional competence	●	●	●	●
Ability to summarize			●	●
Organizational communication ability	●	●		
Ability to analyze and solve problems			●	●
Management ability	●	●		
Teamwork ability	●	●	●	●
Language expression ability		●		
Engineering practice ability	●		●	●

2 Teaching Content

2.1 Improve the Proportion of Practical Teaching and Pay Attention to the Training of Students' Practical Ability

The course of photoelectric equipments principle and test maintenance can be divided into two parts: equipments theory and practice. The theory part mainly includes the equipments principle and maintenance principle, and the practice part mainly includes the routine operation, testing and troubleshooting of the equipments. In the past, the class hours of theoretical and practical accounted for a similar proportion. According to the teaching situation and student feedback of many years of post education, the acceptance ability and learning interest of post training students are significantly lower than those of undergraduate students, and their learning interest mainly focuses on practical courses closely related to the post. From the perspective of undergraduate training objectives, students should not only learn the theoretical knowledge of equipments, but also cultivate their practical ability. In order to better meet the needs of vocational education in the army, we plan to further increase the proportion of practical courses and give students more opportunities to practice on equipments. The target of capability training is shown in Table 1.

2.2 Refine the Knowledge of Equipment Principle and Optimize Equipment Practice Content

In order to mobilize the enthusiasm and initiative of the students and improve their ability to analyze and solve problems independently, we optimized the content of the theory course. On the basis of giving consideration to the comprehensiveness and integrity of the content, we enhanced the comprehensiveness and design of the experiment. According to the principle of photoelectric countermeasure, two comprehensive experiments of laser warning and laser jamming are mainly carried out. The experimental contents almost cover all the main contents of photoelectric countermeasure system theory.

1) **Laser warning**

Laser warning equipment is a photoelectric reconnaissance equipment used to intercept, measure, identify enemy laser threat signals and give real-time warning [5, 6], which is used to detect the direction, coding rules and other technical parameters of the incoming enemy laser radiation. At the same time, the warning signal can also be sent to the photoelectric jamming equipment through the interface to generate the synchronous jamming signal. The divergence angle of the beam emitted by the laser indicator is very small, so when analyzing the warning distance, it is necessary to consider the intensity distribution of the laser beam. As shown in the Fig. 2, in the case of direct detection, assume that the laser output power is $P(t)$, the output laser beam is Gaussian distribution, and its far field divergence angle is θ. Without considering the effects of atmospheric turbulence, the laser irradiance distribution E_L in the plane perpendicular to the optical axis at R is [7]

$$E_L(t, d_x) = P\left(t - \frac{R}{C}\right)e^{-\mu R}\frac{4}{\pi\theta^2 R^2}e^{-\left(\frac{2d_x}{\theta R}\right)^2} \quad (1)$$

where μ is the atmospheric extinction coefficient.

Generally, the laser beam will not directly aim at the warning device. When considering the atmospheric scattering, the scattering receiving model of the laser warning is shown in the Fig. 3.

Assume laser output power is P, the laser beam is transmitted horizontally, the diameter of the output spot is $D0$, the divergence angle is α_0, D is the observation point whose off-axis distance from the laser beam is d, the horizontal distance between the laser and point A is R, the distance from point X to point D in the transmission path is

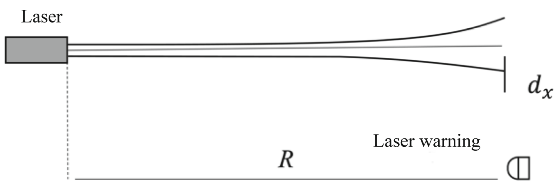

Fig. 2. Direct detection of laser warning

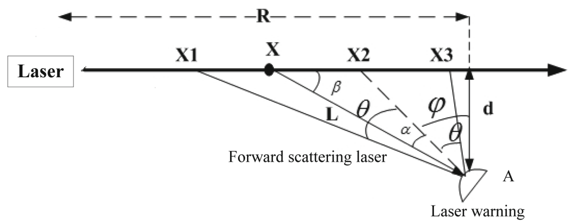

Fig. 3. Scatting detection of laser warning

L, the detection square angle of the scattering detection equipment is ϕ, the detection field is 2θ, the intersection points of the detector field and the laser beam are $X1$ and $X3$, and the off-axis distance of the detector is d, The atmospheric attenuation coefficient of laser is σ.

If the normal direction of the detector is parallel to the laser beam, i.e. $\phi = \pi/2$, and the field of view of the detector is large enough to cover the entire laser transmission path, the scattered laser irradiance received by the warning device is [7]

$$E_P = \int_{\beta_0}^{\pi/2}\int_{r_1}^{r_2} 10^{-13}\frac{P\lambda^2\cos\beta}{8\pi^2 d}\cdot\left[|S_1(\beta)|^2 + |S_2(\beta)|^2\right]\cdot N(r)\cdot\exp(-\sigma\cdot(R - d\cot\beta + d/\sin\beta))\cdot drd\beta \quad (2)$$

where $\beta_0 = arctg\left(d/R\right)$, $N(r)$ is number of aerosol particles, $/(cm^3\cdot\mu m)$, r is aerosol particle size, μm.

According to the above two formulas, the relationship between laser irradiance and off-axis distance can be drawn. As shown in Fig. 4.

It can be seen that the irradiance of the direct beam on the off-axis warning device decreases sharply with the increase of the off-axis distance d. When the off-axis $d = 10m$, the irradiance decreases by nearly 5 orders of magnitude compared with the optical axis center. In laser warning applications, it is necessary to use the scattering of the atmosphere to detect the laser signal.

2) **Laser jamming**

a) *Laser angle deception jamming*

Laser angle deception jamming is to place a laser diffuse reflection decoy at an appropriate position around the target protected by your side [8]. After decoding, the laser jammer gets the decoding of the laser guidance signal, and generates the relevant laser jamming signal. The laser jammer sends the laser jamming signal to the decoy. The laser seeker of the semi-active laser guided weapon at a certain direction

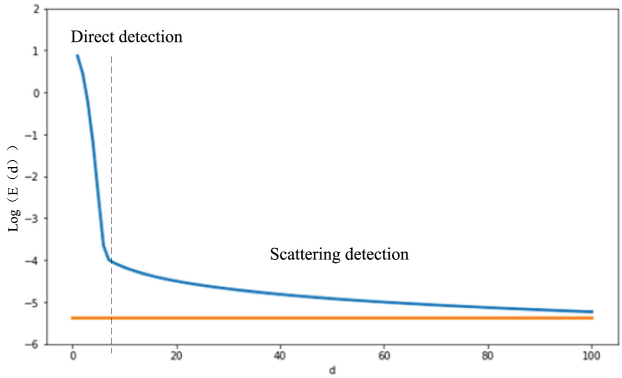

Fig. 4. Distribution of irradiance with off-axis distance for direct detection and scattering detection

away from the diffuse reflector plate receives this jamming signal, then the seeker mistakenly identifies the jamming signal as the guidance signal, it indicates that the seeker has been deceived. The seeker will deviate from the correct direction in the following homing process, controlling the projectile to fly towards the false target of the diffuse reflector plate that we have arranged in advance, thus avoiding the real target, it protect your important targets from attack. The principle diagram of laser angle deception jamming is shown in Fig. 5.

In principle, the sign of successful jamming is to make the jamming pulse enter the range of the receiving gate of the seeker as much as possible and be ahead of the laser guidance signal. See Fig. 6 for the relationship among the seeker gate width, laser target indicator signals and deception signals.

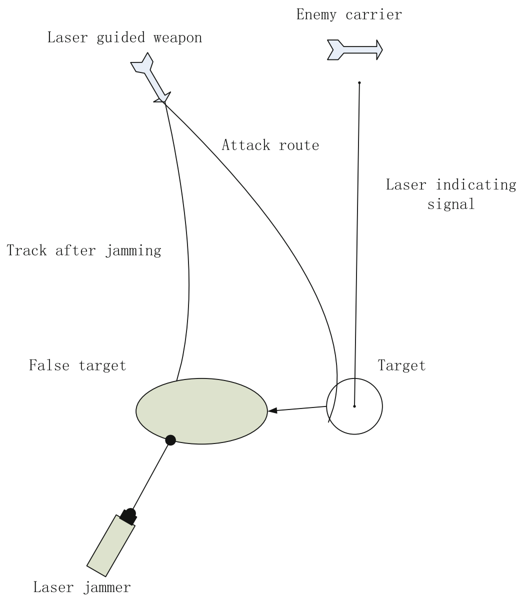

Fig. 5. Schematic Diagram of Laser Angle Deception Jamming

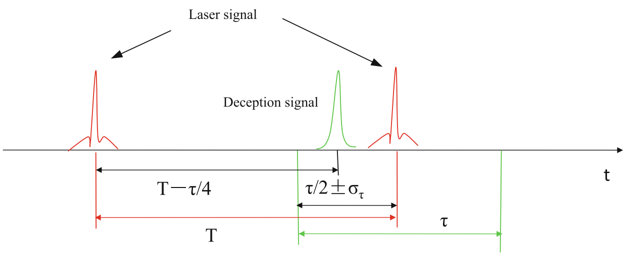

Fig. 6. Relationship between deception signal and laser signal

In which, T is laser indication signal pulse interval, τ is width of seeker gate, σ_τ is time jitter.

b) *Laser high repetition frequency jamming*

Because the laser semi-active guidance weapon generally adopts the anti-jamming technology such as coding and gate, and the time for confrontation is very limited, this requires very high requirements for the warning system, which makes it difficult to achieve the success of angle deception jamming. The technology of using the laser with high pulse repetition rate to jam the seeker is called high repetition frequency jamming [9], also called blocking jamming. As a new means of photoelectric jamming, the high repetition rate laser does not need to decode, identify the laser guidance signal. As long as the repetition frequency is high enough to ensure that at least one or more jamming pulses receive by seeker, thus greatly improving the initiative and adaptability of the countermeasure. Its principle is shown in the Fig. 7.

Although the code and gate parameters of the seeker are not known, the principle that high repetition frequency jamming still works can be illustrated in Fig. 7. The horizontal axis in the figure represents time, and the solid arrow represents guidance pulse, as shown in Fig. 7(a). The rectangular box represents the gate, as shown in Fig. 7(b). The gate is open at the time when each guidance pulse occurs, as shown in Fig. 7(c). The imaginary arrow indicates the high repetition frequency jamming pulse, as shown in Fig. 7(d). If the pulse repetition frequency of the jamming laser is high enough (the jamming pulse corresponding to the Fig. 7(d) is denser on the time axis), so that there are at least two jamming pulses in the time when the seeker's gate is opened, as shown in figure (e), the probability of the jamming pulse appearing in the gate before (or behind) the guidance

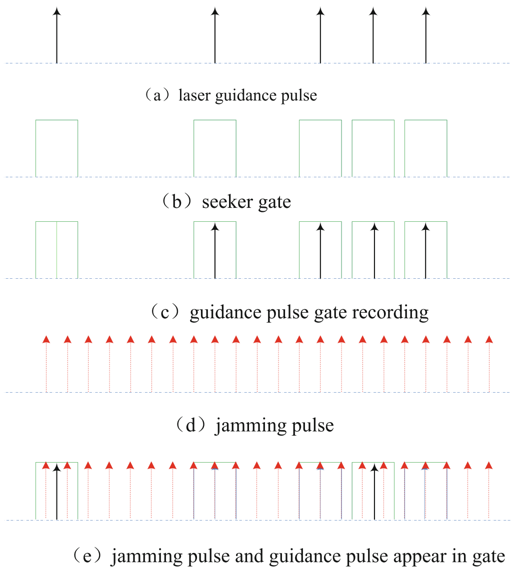

Fig. 7. Seeker gate and signal recording

pulse is high. Obviously, the higher the repetition frequency of the jamming pulse and the stronger the jamming energy are, the greater the probability of successful jamming to the seeker is.

3 Teaching Mode

3.1 Optimize Teaching Subjects and Teach in Groups

Because of the long duration of the course, the large number of students, and the small number of equipment and teachers, only 2 ~ 3 students can be accommodated in one equipment vehicle at the same time, if centralized teaching is adopted for the practical teaching, most of the students can only be spectators, and their practical ability cannot be trained, in order to get better teaching effect, we must teach in groups.

Relying on the construction of courses and laboratory conditions, we have produced multimedia teaching films and maintenance cases, and at the same time, we have divided the course content into multiple teaching subjects, such as equipment unit technology, disassembly of equipment unit, equipment parameter test, simulated maintenance experiment and practical maintenance training. All the students are divided into several groups, and each group of students is arranged to learn different subjects. After completing the required subjects, they will rotate. Although this puts forward higher requirements for teachers and organizer, it can obviously shorten the queuing time of students and greatly improve the learning efficiency.

3.2 Contact with Practice and Scientifically Design Teaching Plan

There are many teaching links in the course of photoelectric equipments principle and test maintenance. If the teaching plan is not designed scientifically and reasonably, There will be problems in the connection between teaching links [10], which will seriously affect the quality of teaching. In the past, we used to implement teaching in the order of equipment principle, maintenance principle, standard equipment operation and test. Although this arrangement is simple and clear in structure and easy to organize, we have also found a problem in many years of teaching practice, that is, the theory and practice are not closely linked. Due to the large time span of the course, if the trainees can't touch the real equipments in the theoretical study in the first few weeks, they can only learn and understand abstractly, In the follow-up practice, the theoretical knowledge learned previously may have been forgotten and cannot be connected with the real object. In order to solve this problem, on the one hand, we plan to change the teaching plan and interlace the theoretical and practical courses. For example, 5 ~ 6 classes in the afternoon are arranged to teach principle knowledge, and 1 ~ 4 classes in the morning are arranged to practice equipment, so that principle teaching and practice teaching can promote each other. On the other hand, we plan to change the teaching method of the theory course, and the instructor will lead the students to learn the structure of the equipment, the working principle of each sub equipment and the signal flow in comparison with the real object on the equipment vehicle, so as to make the theory teaching more specific.

Table 2. Comparison of different teaching modes

Teaching mode	Traditional mode	Four skills mode
Instrument and equipment damage/%	10–20	1–5
Teacher's operation and explanation time/min	40–60	15–20
Accuracy of experimental data/%	60–80	80–90
Subject Competition/num	0	4
Graduation Design/num	0	6

Data from the past five years

3.3 Change the Teaching Method and Stimulate the Students' Initiative

In the past, we used the teaching method of teachers' explanation first, then standard equipments demonstration, and finally students' experience. In this process, students are basically in a passive receiving state [11]. This will cause students to remember and understand the teaching content unclear. Moreover, when the number of students divided into groups is large, repetitive teaching will also make teachers physically and mentally exhausted, this will affect teaching quality. In order to change this situation, we try to adopt the teaching method of "classroom inversion". First, the instructor will explain and demonstrate to the first group of students. After the students have completed the experience, this group of students will teach and demonstrate to the next group of students, and then transfer to the last group. Students are both learners and lecturers in this process. At the learning stage, the students will pay high attention so as to complete the following teaching; In the teaching stage, students can sort out the knowledge points they have learned before and deepen their understanding. In the process of transmission, students' understanding and memory will inevitably have deviations and omissions, which requires teachers to supplement, correct and comment at the end. For this teaching method, students believe that they can not only learn equipments knowledge, but also exercise their teaching ability, which will help them to better adapt to their posts in the future.

It can be seen from Table 2 that the new teaching mode is compared with the traditional teaching mode in terms of instrument and equipment damage, teacher's operation and explanation time, accuracy of experimental data, subject competition and graduation design. The data of the past five years show that the new teaching model is successful.

4 Organization and Implementation

4.1 Reasonably Assign Tasks and Clarify Responsibilities

The practice of this course involves many groups of students, many types of equipment, many training subjects, and many teaching and support personnel, all of which increase the difficulty of organization and implementation, the whole teaching process may become confused and random. We adopt one lecturer and several instructor for implementation. Each day, the lecturer arranges the teaching tasks of each instructor according to the teaching progress, formulates an accurate teaching plan through centralized discussion, specify the subjects to be carried out, the instructor in charge of the subject and the teaching standard of the subject. In order to give consideration to the flexibility of implementation, we also arrange a standby instructor and subjects every day, Prevent unexpected situations of the planned instructors or equipments.

4.2 Serious Teaching Order and Prevention of Freedom and Carelessness

In teaching plan, about 2 h of training is arranged for each subject, and more than 4 groups of students take turns to do experiments. In the case of frequent flow of students, if the teaching order cannot be strictly controlled, it is easy to move around freely, laugh and play, sleep and play with mobile phones. Therefore, we learned from the experience of combat service courses and formulated a series of teaching and training specifications. At the beginning of each course, the instructor will assign tasks, and the backbone of the students will organize equipment erection and withdrawal. The instructor of the subject shall be responsible for the management, and the order in the classroom shall be in the charge of the instructor who undertakes the simulation experiment teaching. During student rotation, it is not allowed to stay outdoors at will. At the end of the course of the day, the lecturer will summarize and comment on the reports of each instructor, and the performance of each group of students will be used as the basis for the final score evaluation.

4.3 Improve Assessment Mode and Strengthen Comprehensive Evaluation

We tried to divide the experiment results into six parts, as shown in Table 3. The process oriented, quality and ability centered formative assessment and comprehensive assessment method are more objective, more reasonable, and more easily accepted by students.

In the table, the design of experimental scheme or plan, the completion of experiment operation, the analysis of experiment report and the mastery of experiment method account for a large proportion, reflecting the overall quality of experiment completion. This is also the basis for improving students' practical ability and scientific research innovation ability. This evaluation method of combining formative evaluation and comprehensive evaluation, which is process oriented and quality and ability centered, is more objective, more reasonable and easier to be accepted by students.

Table 3. Project scoring standard

Scoring standard	*very bad*	*bad*	*good*	*very good*	*excellent*
Whether the experimental plan can be formed according to the requirements of the experimental content. [15 points]	0 ~ 4	5 ~ 8	9 ~ 11	12 ~ 13	14 ~ 15
Whether the time can be arranged according to the experimental plan and the team members can be reasonably arranged to work effectively. [5 points]	0 ~ 1	2	3	4	5
Whether problems can be found, solved and discussed during the experiment. [20 points]	0 ~ 5	6 ~ 11	12 ~ 15	16 ~ 18	19 ~ 20
Whether the theoretical knowledge required by the experiment is mastered and correctly applied. [20 points]	0 ~ 5	6 ~ 11	12 ~ 15	16 ~ 18	19 ~ 20
Whether the experimental instrments and methods can be mastered. [30 points]	0 ~ 8	9 ~ 17	18 ~ 23	24 ~ 27	28 ~ 30
Whether it is possible to put forward suggestions for improvement and continuous improvement based on the preliminary results of the experiment. [10 points]	0 ~ 2	3 ~ 5	6 ~ 7	8 ~ 9	10

5 Conclusions

The teaching reform of photoelectric equipments principle and test maintenance has always been oriented to the needs of the army, it greatly enriched the teaching content, strengthened the practice link, and paid attention to the theory, practicality and pertinence, which has achieved good teaching results in improving the post holding ability of students. The pass rate of trainees in the joint assessment of professional quality is 100%. The leaders of the department and the teaching supervision group gave high evaluation. Most of the students not only mastered the theoretical knowledge of various types of photoelectric equipments, mastered the analysis ideas of common faults, but also exercised a certain practical ability. According to the feedback of the graduates in recent years, they have generally mastered the rich equipment theory and skilled equipment operation, testing and maintenance capabilities through the study of this course, and can quickly adapt to the military posts. In the future, we will closely follow the development of photoelectric equipments, focus on practical teaching, continue to increase reform in teaching content, teaching methods, and strive to cultivate high-quality military personnel who meet the needs of electronic forces and have high professional quality, innovation awareness and practical ability.

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References

1. Chen Shenhai, Wang Jun, Dai Wei, Wang Yanfen, Mao Huiqiong, Li Ming, "Research and exploration on application of engineering project to undergraduate experimental teaching," Experimental Technology and Management, Vol.35, pp178-181, August 2018.
2. Li Jianlin, Zheng Jidong, Guo Xiaoming, Lin Yun, Liu Yonghe, "Design of engineering comprehensive experiment on computer," Experiment Science and Technology, Vol.16, pp35-39, August 2018.
3. Shi Shenghui, Luo Binbin,Zou Xue, Tang Bin, Zhong Nianbing, Jiang Shanghai, Song Tao, Wu Decao, Zhao Mingfu, " Exploration on the Training Mode of Innovative and Versatile Talents in Optoelectronic Information Specialty," Education Modernization, Vol.83, pp 192-194, October 2019.
4. Tang Qiu, Zhang Xiaogang, Zhang Fan, Wang Shi, Zhao Renxin, " Experimental teaching reform of "Three combinations" in "Automatic control principle" course under background of "New engineering"," Experimental Technology and Management, Vol.38, pp 197-200, March 2021.
5. Yang Zaifu, Qian Huanwen, Gao Guanghuang, "Development of laser warning technology," Laser Technology, Vol.28, pp98-102, February 2004.
6. Zhang Fang, Ren Huajun, "Status and Development Trend of Laser Surveillance and Warning Technology," Modern Information Technology, Vol.3, pp44-46, May 2019.
7. Lv Yaoguang, Sun Xiaoquan, Fundamentals and Application of Laser Countermeasures. National Defense Industry, Beijing, 2015.
8. Zhang Yingyuan, "Warning and Deception Jamming Technology of Laser Countermeasure," Phd thesis, Xidian University, 2012.
9. Zhu Chencheng, Nie Jinsong, Tong Zhongcheng, "Analysis on the mode of high repetition laser jamming, " Infrared and Laser Engineering, Vol.38, pp1060–1063, December 2009.
10. Xu Guiwen, Zhang Fengxia, Wu Honglei, "Innovation of Large-scale Instrument Experimentation Teaching in Colleges and Universities Based on Situation and Case," Education and Teaching Forum, Vol.49, pp 69-73, December 2021.
11. Xue Qiaoqiao, Wu Yuanming, "Research and Practice of Training Mode for Optical Engineering Talent," Higher Education Forum, Vol.7, pp 40-43, July 2011.